

Appendix B

Preliminary Program Impacts Results

This appendix presents preliminary estimated impacts from CSI projects that were completed through the end of 2008. Impacts include effects on energy delivery; peak demand; GHG emissions and on the transmission and distribution systems. Impacts were examined at a program-wide level and to the extent data were available, at Program Administrator (PA)-specific levels. Results are preliminary as a limited amount of metered data was provided to Itron at the time of the analysis. The impact results will be finalized after additional metered data becomes available.

Impacts are usually estimated based on combination of metered data, project information and engineering methods (e.g., methods for estimating the performance of sites for which metered data was not available). Itron did not install and collect independent metered data for this 2007-08 impact evaluation. Instead, metered data was collected from third party data providers; primarily Performance Data Providers (PDPs) and Performance Monitoring and Reporting Services (PMRS) contractors. Metered data were received from third party data providers for only a small proportion of completed projects. Consequently, this annual impact evaluation relies on a combination of metered data and engineering estimates to determine the program impact on demand during the peak hour as well as the annual energy contribution. Additional metered data is being provided to Itron over the next two months. The impact evaluation results will be updated once the additional metered data has been collected, processed and analyzed.

This section is composed of the following five subsections:

- B.1: Program Status in 2008
- B.2: Electric Energy Impacts
- B.3: Electric System Peak Demand Impacts
- B.4: Transmission and Distribution System Impacts
- B.5: Greenhouse Gas Emission Impacts

B.1 Program Status in 2008

Table B-1 provides a summary of the number and rebated capacity of CSI projects among several different customer types as of the end of 2008. Residential projects represented the

majority of the total number of projects, but just under half of the total rebated capacity. Commercial projects represented 50 percent of the total rebated capacity. There were more non-profit projects than government projects. However, the government projects were larger and represented slightly more of the total rebated capacity.

Table B-1: CSI Projects and Rebated Capacity by Customer Type (12/31/08)

Customer Sector	Complete		Active Online		Total		
	(n)	(MW)	(n)	(MW)	(n)	(MW)	% MW
Residential	10,034	46	1,005	5	11,039	50	33%
Commercial	427	51	159	34	586	84.6	56%
Non-Profit	89	2	20	1	109	2.7	2%
Government	45	3	49	10	94	12.8	8%
Totals	10,595	101.7	1,233	48.7	11,828	150.3	100%

It is also useful to examine the growth in capacity of CSI PV systems installed over time by customer type. Due to their similarity in size and operational aspects¹, we have grouped residential and small commercial (i.e., those commercial applications where the PV system is less than 10 kW in rebated capacity) together. We have also deemed “large” commercial systems to be those PV systems on commercial applications that are equal to or greater than 10 kW in rebated capacity. Table B-2 is a summary of CSI projects using these groupings.

Table B-2: CSI Projects and Rebated Capacity by Customer Grouping (12/31/08)

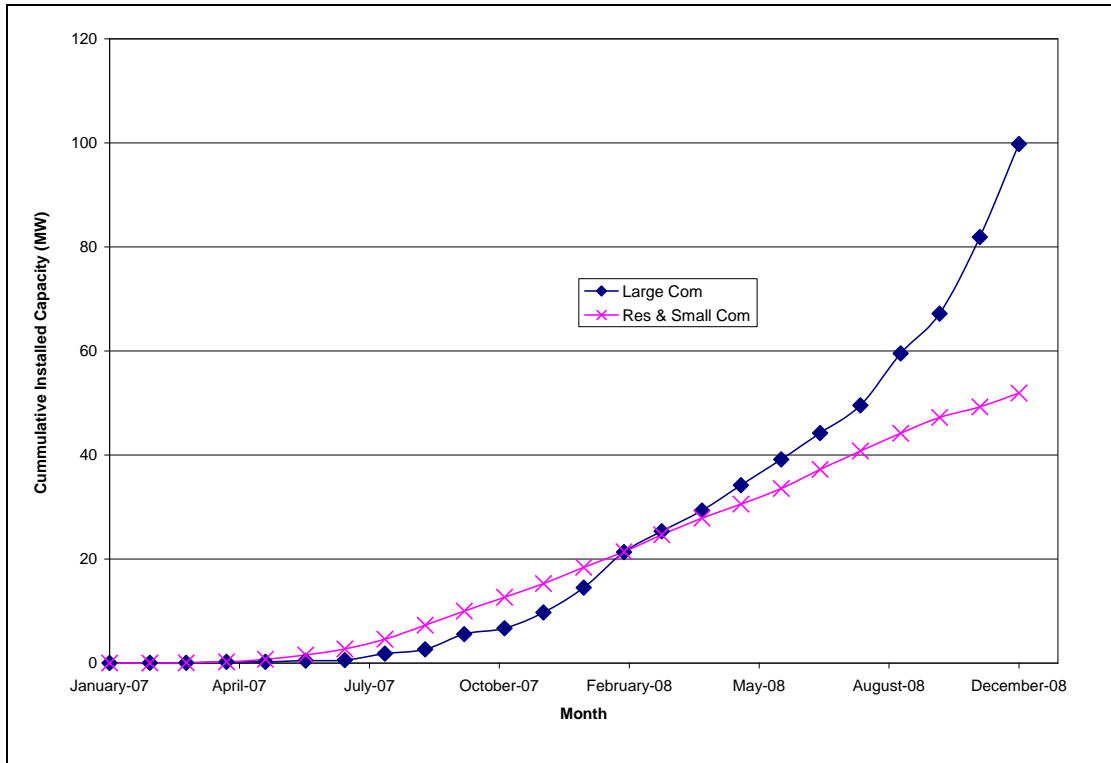
Customer Grouping	Complete		Active Online		Total		
	(n)	(MW)	(n)	(MW)	(n)	(MW)	% MW
Res & Small Com	10,239	46.8	1,044	4.7	11,283	51.6	34%
Large Com	356	54.8	189	43.9	545	98.8	66%
Totals	10,595	101.7	1,233	48.7	11,828	150.3	100%

Although 11,828 sites were online at the end of 2008, many of these sites came on throughout the year and therefore only produced electricity for a fraction of the months. This must be taken into account when estimating the annual and peak impacts of the program. Figure B-1 presents the cumulative completed capacity by month for both residential and non-residential customer sectors. The large commercial segment had a slower start than the combined residential and small commercial segment but by early-2008 the cumulative capacity of completed large commercial projects exceeded that of residential and small

¹ By operational aspects, we refer to the types of servicing or maintenance activities that may be conducted by the system owner, including washing of panels, etc.

commercial projects. A continued high growth rate in large commercial projects will have significance on impact evaluation results in the future. Large commercial projects are likely to have different operating characteristics, costs and affects on the electricity transmission and distribution systems than the residential and small commercial facilities.

Figure B-1: Cumulative Completed and Active On-Line Capacity by Month



B.2 Electric Energy Impacts

This section presents the annual energy and non-coincident demand impacts for the overall program as well as for each PA.

Overall Program Energy Impacts

Electrical energy and demand impacts were estimated for projects completed or deemed to be active on-line prior to December 31, 2008. Impacts were estimated using available metered data for 2007-2008 and information on system characteristics. Information on system characteristics came from project tracking systems maintained by the PAs.

By the end of 2008, there were 11,828 complete or active on-line CSI PV systems providing over 150 MW of electric generating capacity. Table B-3 provides the estimated quantity of

electric energy delivered by SGIP facilities for each quarter throughout calendar years 2007 and 2008.

Table B-3: Estimated CSI Statewide Energy Impact in 2007-2008 by Quarter

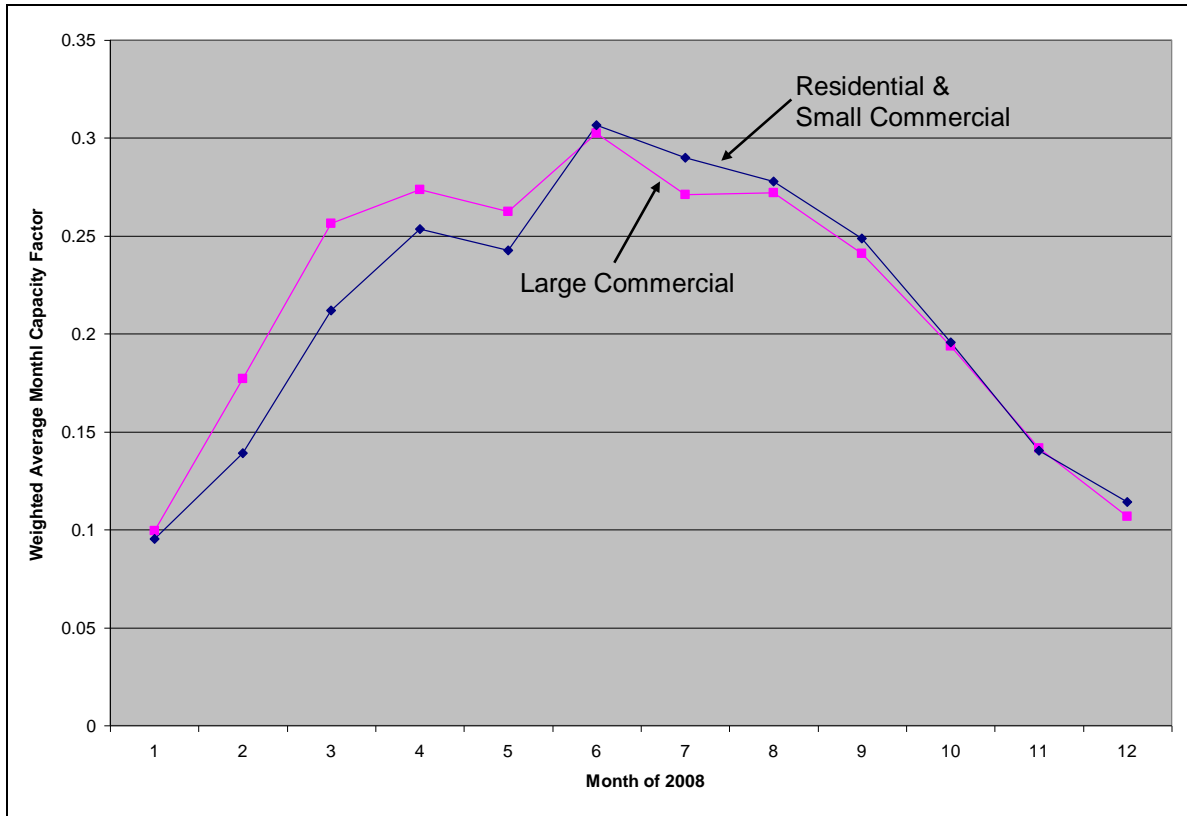
Year	Q1 (MWh)	Q2 (MWh)	Q3 (MWh)	Q4 (MWh)	Total (MWh)
2007	0	462	2,653	4,634	7,749
2008	14,818	35,194	46,169	39,329	135,510

Less than 7,800 Megawatt-hours (MWhr) of electricity was delivered by CSI PV facilities during 2007. This was the first year of the CSI and only 19 MW of PV capacity was installed in 2007; 72 percent of which came online during the last three months of the year. However, estimated electricity delivered increased 17-fold by the end of the following year as significantly more facilities came on-line. CSI projects generated nearly 136,000 Megawatt-hours (MWh) of electricity during 2008; enough to meet the electricity requirements of approximately 20,300 homes for a year². CSI projects are located at utility customer sites whereby they help meet on-site electricity needs. Consequently, the 136,000 MWh of electricity provided by CSI facilities during 2008 represents electricity that did not have to be generated by central station power plants or delivered by the transmission and distribution system.

In addition to examining the amount of energy delivered annually by CSI PV systems, it's also valuable to know the variation in energy delivery during the course of the year. Capacity factor represents the fraction of rebated capacity that is actually generated over a specific time period. Consequently, capacity factor is useful in providing insights into the capability of a generating technology to provide power during a particular time period. For example, annual capacity factors indicate the fraction of rebated capacity that could, on average, be expected from that technology over the course of a year. Similarly, average monthly capacity factors represent the fraction available, on average, during any particular month. Weighted average monthly capacity factors for 2008 are shown in Figure B-2.

² Assuming the typical home consumes approximately 6,670 kWh of electricity per year. From Brown, R.E. and Koomey, J.G. "Electricity Use in California: Past Trends and Present Usage Patterns" Lawrence Berkeley National Laboratory. May 2002. Value derived from Table 2 on page 8.

Figure B-2: Weighted Average 2008 Capacity Factors by Month for Metered Systems



Capacity factors during the summer months peaked at 0.3 in June and dropped to 0.1 in January. The annual average capacity factor for CSI PV systems for 2008 was 0.20.

PA-Specific Energy Impacts

Table B-4 provides annual energy impacts for CSI projects by each PA for both 2007 and 2008 and the corresponding number of PV systems installed in those years.

Table B-4: Estimated CSI Annual Energy Impacts by Year and PA (MWh)

Year	PG&E		SCE		CCSE		Total	
	(n)	(MWh)	(n)	(MWh)	(n)	(MWh)	(n)	(MWh)
2007	2472	4,989	633	1,468	322	1,292	3,427	8,704
2008	7922	74,944	2842	48,299	1064	12,268	11,828	139,416

PV systems installed in the PG&E area supplied nearly 54 percent of the total electricity delivered by the CSI in 2008, whereas SCE and CCSE systems supplied approximately 35 percent and 9 percent, respectively. The magnitude of electricity delivery in the PG&E

territory is not surprising given that PG&E had over 7,900 PV systems operating in 2008; nearly 67 percent of all systems installed under the CSI that year.

Table B-5 provides annual capacity factors for CSI projects by PA for 2008. 2007 data is not presented since few systems were operational for the majority of 2007.

Table B-5: Estimated Annual Capacity Factors for 2008 by PA

Year	PG&E	SCE	CCSE
	Annual Capacity Factor (kW _{yr-avail} /kW _{yr-rebated})		
2008	0.18	0.22	0.20

B.3 Peak Electricity Demand Impacts

This section presents estimates of the peak electricity demand impacts for the CSI as a whole. A program-wide examination of peak demand impact was based on the electricity produced by CSI projects coincident to the California Independent System Operator (CAISO) system peak for 2007 and 2008.

Overall Program Peak Demand Impacts

The ability of CSI projects to supply electricity during times of peak demand represents a critical impact. By providing electricity directly at the customer site during peak hours, CSI facilities reduce the need for utilities to power up peaking units to supply electricity to these customers. As a result, the CSI provides grid benefits by alleviating the need to dispatch older and more expensive peaking generators as well as by decreasing transmission line congestion. In addition, by offsetting more expensive peak electricity, CSI projects provide potential cost savings to their host sites.

Peak loads and dates of the CAISO peaks for 2007 and 2008 are listed in Table B-6. Interestingly, the CAISO annual system peak load for both 2007 and 2008 occurred from 2:00 to 3:00 p.m. In addition, peak load in both years exceeded 46,000 MW.

Table B-6: Loads and Dates of CAISO System Peak for 2007 and 2008

Year	Peak Load (MW)	Date and Time
2007	48,835	August 31, 2:00 to 3:00 P.M. (PDT)
2008	46,789	June 20, 2:00 to 3:00 P.M. (PDT)

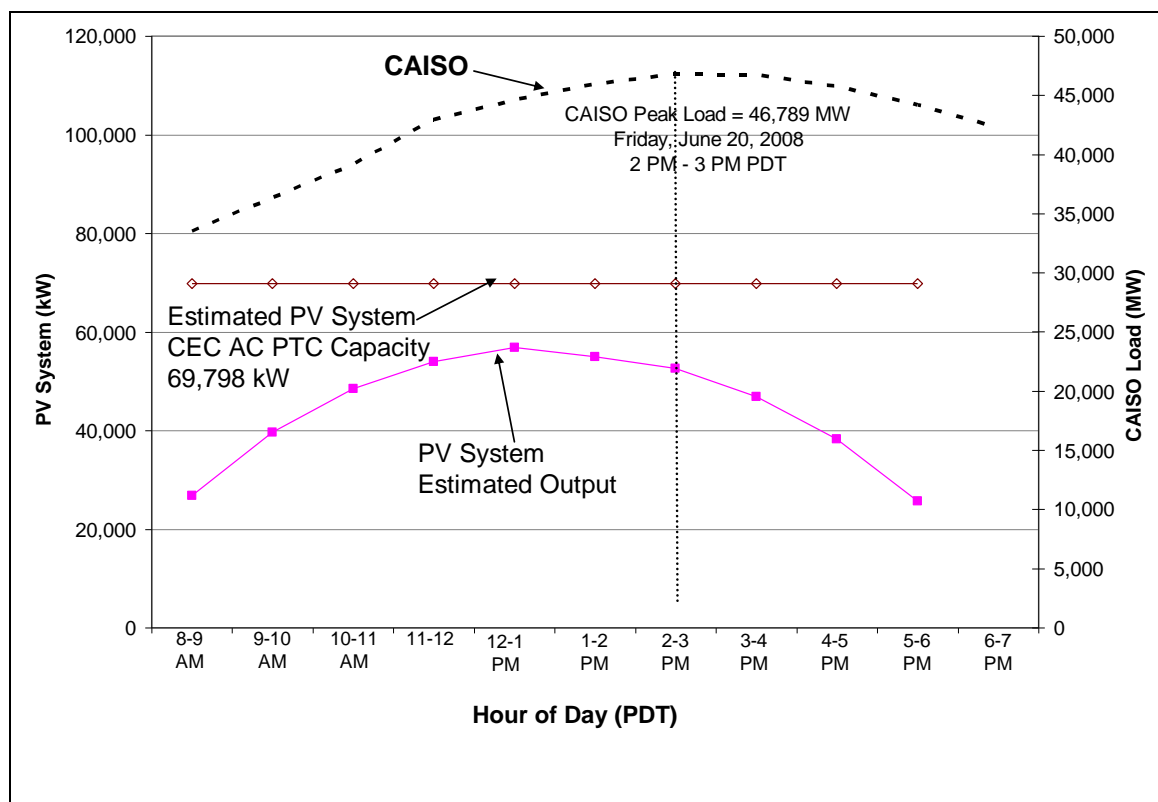
Table B-7 shows the number of systems which were online during the CAISO peak in 2007 and in 2008. The number of on-line systems for 2007 is lower than the on-line number for 2008 because approximately 5,300 more systems were installed after the CAISO peak occurred in June 2007. Table B-7 also provides information on the overall CSI program impact on electricity demand coincident with CAISO system peak loads in 2007 and 2008. Figure B-3 shows the estimated impact of CSI projects on the 2008 CAISO system peak.

Table B-7: Estimated Demand Impact Coincident with CAISO System Peak

Year	PV Systems On-line During Peak (n)*	Estimated Rebated Capacity (MW _r)	On-Line Peak Capacity (MW _p)	Peak-Hour Capacity Factor (MW _p / MW _r)
2007	1,006	6.4	4.4	0.69
2008	6,322	69.8	52.6	0.75

*This differs from the number of systems online as of December 31, 2008, because approximately 5,500 more systems were installed between June 20, 2008 and December 31, 2008.

Figure B-3: Estimated CSI Impact on CAISO 2008 System Peak



In 2008, the CAISO system reached a peak value of 46,789 MW on June 20 from 2:00 to 3:00 P.M. Pacific Daylight Savings Time (PDT). Over 6300 CSI systems were estimated to be on-line during the 2008 CAISO peak. These CSI systems had a rebated capacity of nearly 70 MW and provided an estimated 55 MW of generating capacity during the peak hour. The PV systems for which Itron had data for 2008 showed a 2008 CAISO peak-hour capacity factor of nearly 75 percent. However, this peak-hour capacity factor is unlikely to be representative of CSI PV systems in general for the CAISO 2008 peak.³ In addition, differences in the 2007 and 2008 peak-hour capacity factors could reflect different profiles of the mixes of systems in each year, but may also indicate the uncertainty in the results due to the limited amount of metered data.

PA-Specific Peak Demand Impacts

Itron also had very limited PV metered data at the Investor Owned Utility (IOU) level for 2007 and 2008. Consequently, while PA-specific peak demand impacts have been estimated, they should not be considered statistically significant. Table B-8 shows the number and estimated capacity of PV systems online during the CAISO system peak by PA and the associated impact on the CAISO peak.

Table B-8: Estimated Peak Demand Impact Coincident with CAISO System Peaks by PA (2008)

Year	Program Administrator	PV Systems On-line During Peak (n)*	Estimated Rebated Capacity (MW _r)	On-Line Peak Capacity (MW _p)	Peak-Hour Capacity Factor (MW _r / MW _p)
2008	PG&E	4,370	39.2	29.6	0.75
	SCE	1,411	24.4	18.4	0.75
	CCSE	541	6.2	4.6	0.75

*This differs from the number of systems online as of December 31, 2008, because approximately 5,500 more systems were installed between June 20, 2008 and December 31, 2008.

In 2008, 69 percent of the systems online (56 percent of the capacity) were installed in PG&E territory.

³ In comparison, SGIP PV facilities for which there was statistically significant metered data, showed a peak-hour capacity factor coincident to the 2008 CAISO peak of 0.58.

B.4 Transmission and Distribution System Impacts

In addition to providing electricity over the course of the year and during times of peak demand, PV technologies being deployed under the CSI impact the distribution and transmission sections of California's electricity system. CSI PV systems reduce loading on the distribution and transmission lines by displacing electricity that would otherwise have to be provided to electricity customers during peak demand. Reduced line loading alleviates the need to expand or build new transmission and distribution infrastructure, thereby saving utility and ratepayer monies. Moreover, by providing multiple pathways for electricity to be delivered to the grid, CSI PV facilities can potentially lower risk of transmission outages, which in turn increases overall system reliability.

This section presents the impacts of CSI PV facilities on the IOU transmission and distribution system during 2008. Transmission system impacts are discussed first, followed by distribution system impacts.

Transmission System Impacts

The 2008 transmission impacts and projections of future trends are described in this section. Insufficient PV output data was available to assess the 2007 transmission system impacts.

At the end of 2008, the total installed generating capacity of grid connected PV in California was less than 500 MW, whereas the 2008 CAISO peak transmission capacity was close to 47,000 MW. Consequently, the electrical output of CSI PV systems installed in 2008 is relatively small in comparison to the capacity of the transmission system as a whole. As market penetration of PV increases in future years, transmission system impacts from PV systems should become greater and more readily observable. While 2007 transmission impacts were not estimated, they would clearly be less than the 2008 impacts due to the lower PV capacity installed in 2007.

Data Requirements

The following data was required to perform the 2008 transmission impact analysis:

- Transmission power flow case files for 2008 summer peak load conditions
- PV generation at time of system peak by service area (PG&E and SCE)

A substation by substation estimate of PV output at 2008 system peak was not available for this analysis.

Data Provided

The 2008 summer peak operating power flow base case was obtained from the Western Electricity Coordinating Council (WECC). The WECC case has limited detail for the PG&E

and SCE transmission systems. Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) provided power flow cases for summer 2008 that includes additional representation of their local transmission systems (e.g., 500kV down to 115kV) and sub-transmission systems (e.g., 66kV). Table B-9 provides a comparison between the 2008 summer peak power flow models provided by PG&E and SCE relative to the WECC 2008 summer peak base case.

Table B-9: Summer Peak Case Comparison

	WECC Case	SCE Case	PG&E Case
Number of buses	15,723	1,924	2,999
Number of branches	13,791	2,058	2,974
Number of areas	21	9	38
Number of zones	402	59	99
Total Load (MW)	159,971.50	29,183.30	26,795.20
SCE Load (MW)	23,934.60	20,991.40	0
PG&E Load (MW)	26,079.30	10	26,790.80
Total Losses (MW)	5,974.70	912.1	1,066.40
Total Generation	165,946.80	30,095.30	27,861.60

The power flow models provided by PG&E and SCE are completely different cases than those prepared for WECC. The PG&E and SCE cases used for this analysis are more detailed about their own systems, but have less detail for the other WECC areas. A comparison of the detailed cases follows.

Detailed 2008 Models by Utility

Table B-10 summarizes the detailed 2008 summer peak power flow cases. These more detailed cases include representations of the sub-transmission system for each utility that is not included in the WECC cases.

Table B-10: Detailed 2008 Summer Peak Power Flow Cases

Model	Area	Load	Losses	Interchange	Generation
WECC	24 SOCALIF	23,934.6	486.9	-8,506.9	15,914.7
	30 PG&E	26,079.3	870.5	-565.7	26,384.1
PG&E	1 thru 30	26,790.8	740.53	-662.6	26,864.9
SCE	8 SOCALIF	20,991.4	618.9	-7,818.6	13,803.4

The detailed PG&E and SCE cases are stand-alone power flow cases and no attempt was made to merge these into the WECC cases.

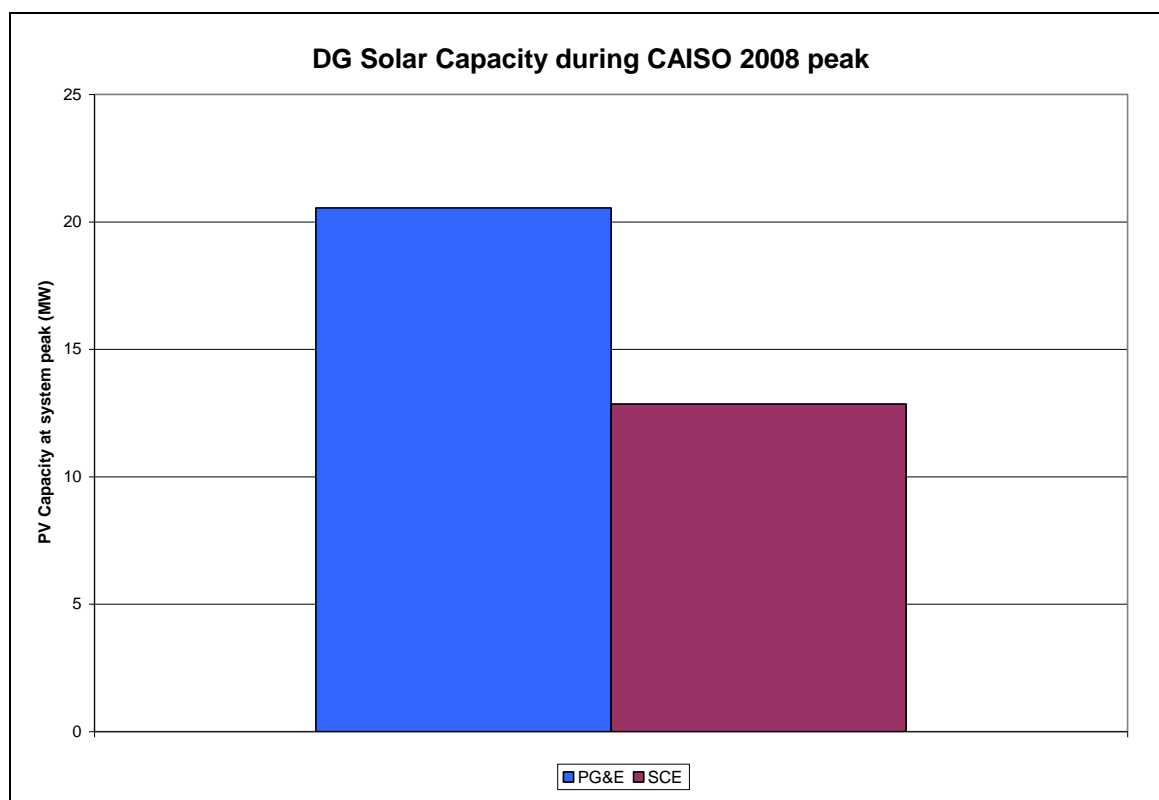
Aggregated 2008 PV Output

KEMA estimated utility-specific transmission impacts occurring at the 2008 CAISO summer peak by aggregating PV capacity on-line at the time of the peak. Estimates of the aggregate PV solar generation output at the time of system peak, by utility, are shown in Table B-11 and Figure B-4.

Table B-11: Aggregated PV Capacity Coincident to Peak Loads

Utility	PV generation (kW)	Date	Hour starting
SCE	12,857.9	6/20/08	1:00 pm (CAISO peak)
PG&E	20,549.6	6/20/08	1:00 pm (CAISO peak)
SCE	10,920.2	6/20/08	3:00 pm (SCE area peak)
PG&E	14,053.5	7/8/08	4:00 pm (PG&E area peak)

Figure B-4: CSI Capacity (SCE and PG&E) During CAISO 2008 Summer Peak



Methodology for Estimating Transmission Impacts

Distributed PV projects are not discretely modeled in the PG&E and SCE transmission power flow cases. For all practical purposes, it can be concluded that the impact of distributed PV on the substation demand levels was also ignored in these cases. Therefore, in

order to evaluate the peak impact of CSI generation on the transmission system, the peak load power flow cases provided by each utility were adjusted by scaling the system load and the generation down in a pro rata manner by the amount of the PV output level for each utility. The comparison of these scaled cases to the original base cases then reflects the net change or impact on the transmission system (as close as can be practically modeled). Sensitivity cases were also run taking all of the generation reduction at a single generating plant location in PG&E and SCE, respectively, and lastly by reducing power imports in lieu of generator reduction. The following metrics were then used to evaluate the transmission impacts.

Transmission Capacity Benefit

Solar DG systems contribute to the deferral of transmission capacity investments by reducing demand-side consumption. Specific impacts from such small penetrations are hard to measure on the transmission system. However, a 2008 Transmission Capacity Benefit (TCB) was calculated for both PG&E and SCE, respectively, based on the PV solar generator peak impacts using the respective transmission power flow models. The TCB calculation method is described in the following section.

TCB Calculation Method

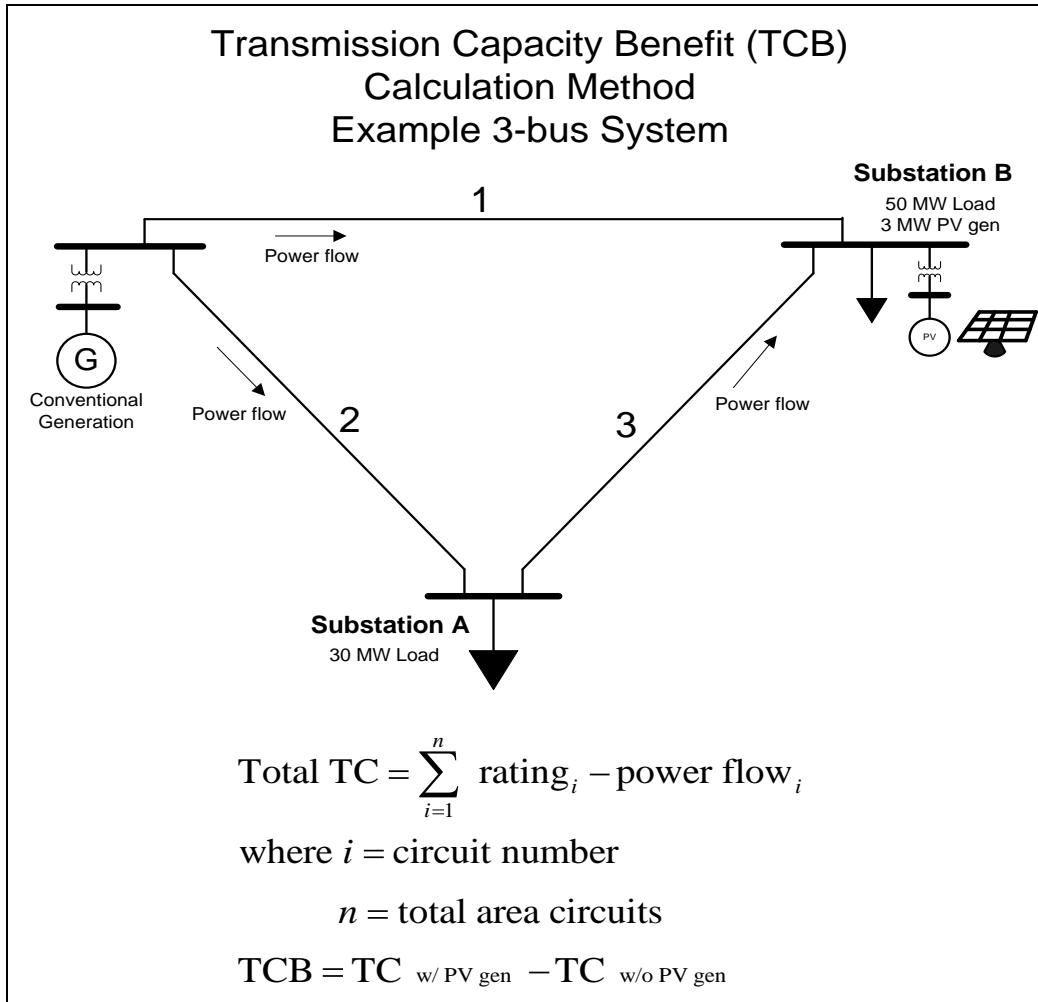
The TCB is the sum of the unused line capacities in the power flow for every “branch” or circuit (i.e., transmission line and transformer) with and without the PV capacity. The difference in unused circuit capacity with PV versus without PV determines the TCB benefit for each utility. The TCB calculation method is illustrated below for a sample 3-bus system in Figure B-5. Results of the TCB example calculation are shown in Table B-12. For simplicity, this example ignores power losses on the circuits and capacitive/inductive flow components.

Table B-12: Example Results of TCB Calculation

Circuit Number	Rating (MW)	Without PV DG		With PV DG	
		Power Flow (MW)	Unused Capacity (MW)	Power Flow (MW)	Unused Capacity (MW)
1	100	35	65	34	66
2	100	45	55	43	57
3	50	15	35	13	37
Totals			155		160

$$\text{TCB (MW)} = 160 - 155 = +5 \text{ MW}$$

Figure B-5: Sample 3-Bus System Showing TCB Method



The TCB represents the increase in transmission capacity made available by adding the distributed PV generation under normal system conditions, and does not address transmission capacity under contingency conditions. Therefore, the TCB is only a metric of transmission benefit and is not useful for any system planning purposes. It should be noted that the value of the TCB in the example above (5 MW) actually exceeds the amount of PV generation added (3 MW), because the additive impact of the flow on the two lines (i.e., lines 2 and 3) that are connected in series between the generator and Substation B where the PV is located. This reflects real transmission capacity “released” on both lines. Thus, even a small addition of PV on the system can result in a cumulative utility TCB value that is larger than the amount of added PV.

Transmission Modeling Sensitivities

The TCB calculation provides a metric or measuring stick to determine the relative impact.

The generator adjustments made to determine transmission capacity impacts were modeled in three different ways in the power flow. One way is to scale the generation down in a pro rata manner in each area by the amount of PV generation in that area. Another way is to reduce area imports by the amount of PV generation in that area. Yet a third way is to back off a single (e.g., marginal cost) unit by the amount of PV generation in that area. None of these ways may accurately represent what actually happens under CAISO open market operation. Table B-13 is a summary of TCB results from the three different modeling approaches used for estimating 2008 CSI transmission impacts within the PG&E and SCE service territories.

Table B-13: Comparison of Transmission Capacity Benefit Modeling Approaches (2008)

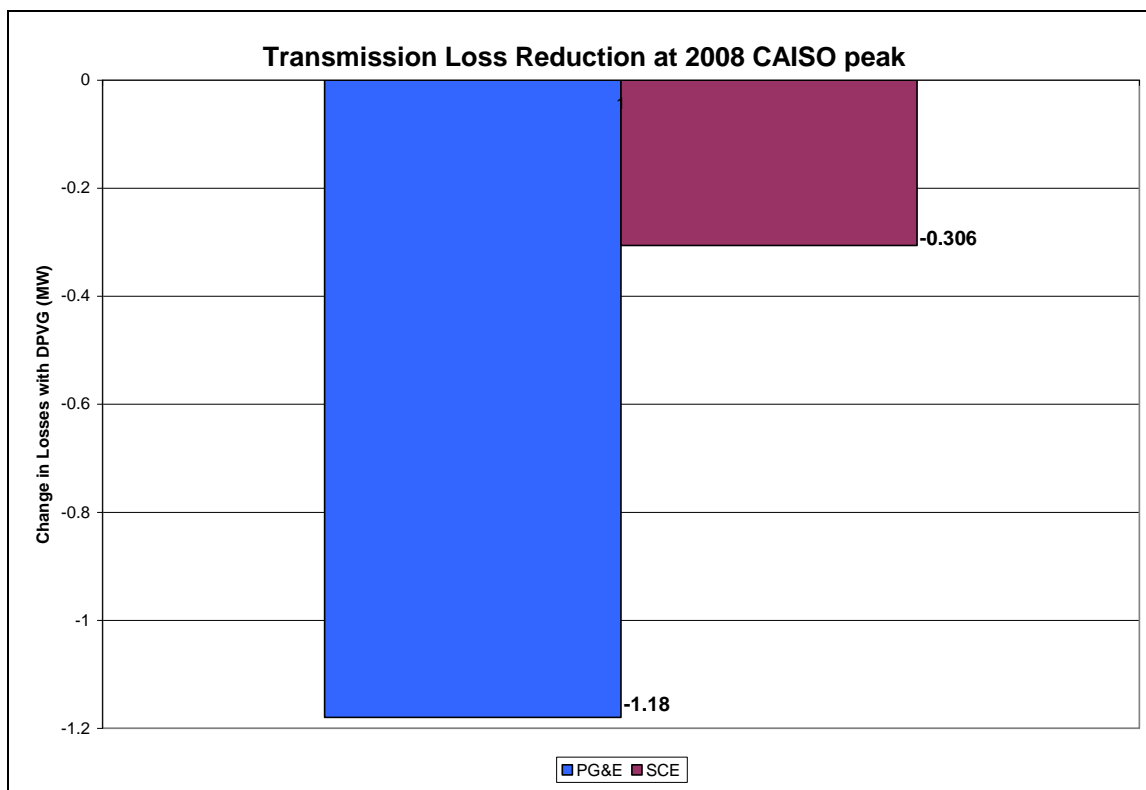
	Scale All Area Generation	Area Import Reduction	Single (e.g., Marginal) Unit Redispatch
TCB Sensitivity Results:			
PG&E Transmission System	83.22	81.63	123.46
SCE Transmission System	46.90	50.95	17.51

Based on these comparisons, scaling area generation was chosen as the best proxy for measuring the CSI PV impacts with results that fall between the other methods.

Actual TCB calculations were done using circuit "mega-volt-amperes" (MVA), but the results were expressed as "mega-watts" (MW) for the purposes of this report.

Peak System Loss Impacts

Solar DG systems can reduce peak system losses by lowering the power delivered by the transmission system at the time of system peak. Distributed PV generation has the same effect as reducing the load at the distribution circuit or transmission bus where the PV power is produced. This results in lower transmission losses, which were quantified using the peak PV generator data in the power flow models provided by each utility. The resulting reduction in transmission losses translates directly into a further reduction in generation requirements and related environmental impacts including emissions. Estimated reductions in SCE and PG&E service area transmission losses are shown in Figure B-6 for 2008 summer peak conditions.

Figure B-6: CSI Impact on Transmission System Losses at 2008 CAISO Peak

System Reliability Impacts

Transmission system reliability is typically measured in terms of the system's ability to deliver power under any n-1 condition⁴. FERC rules generally require that no load be curtailed for any category B contingency (any n-1 contingency or more probable multiple contingencies). However, there is often congestion on the transmission system which can result in reductions in power transfers in order to adhere to this set of reliability criteria. Distributed solar generation improves transmission reliability to the extent that it frees up transmission capacity needed to meet the FERC category B reliability criteria. While no PG&E or SCE contingency analysis was performed for this phase of the study, the Transmission Capacity Benefit (TCB) calculated earlier gives some idea of how the transmission system reliability has improved with distributed solar generation.

Projected impacts of additional distributed PV generation

With increased distributed PV generation, there will continue to be increased savings in transmission losses and freeing of transmission capacity. Figure B-7 shows the projected

⁴ The reliability of the transmission system is typically gauged on the ability of the system to respond to such occurrences as loss of a generator or substation. Consequently, contingency analyses are usually based on a single occurrence (i.e., n-1) versus simultaneous dual occurrences (i.e., n-2).

impact of additional PV generation on the transmission capacity. Similarly, Figure B-8 illustrates the projected impact of additional PV generation on transmission losses. If enough distributed PV generation is implemented, there will be tangible reliability benefits and will result in increases in Actual Transmission Capacity that can be measured.

Figure B-7: Projected TCB Impact Associated with Additional PV Generation

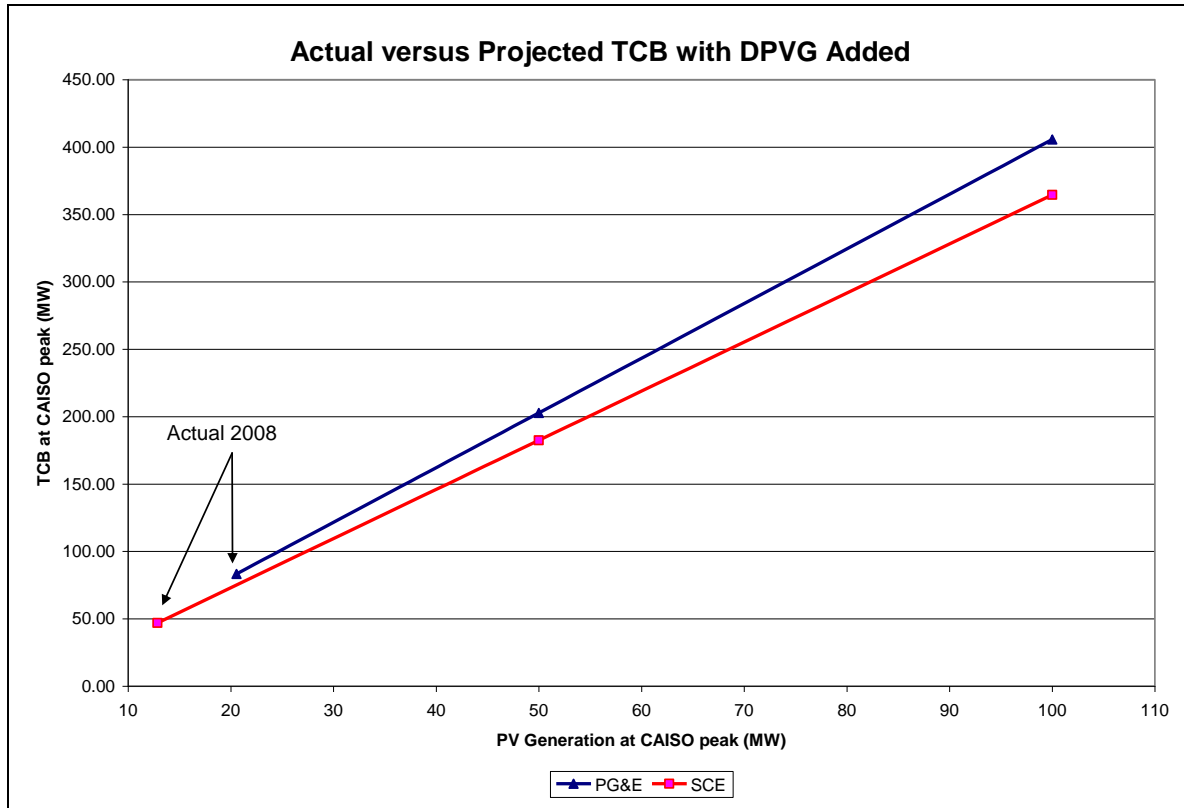
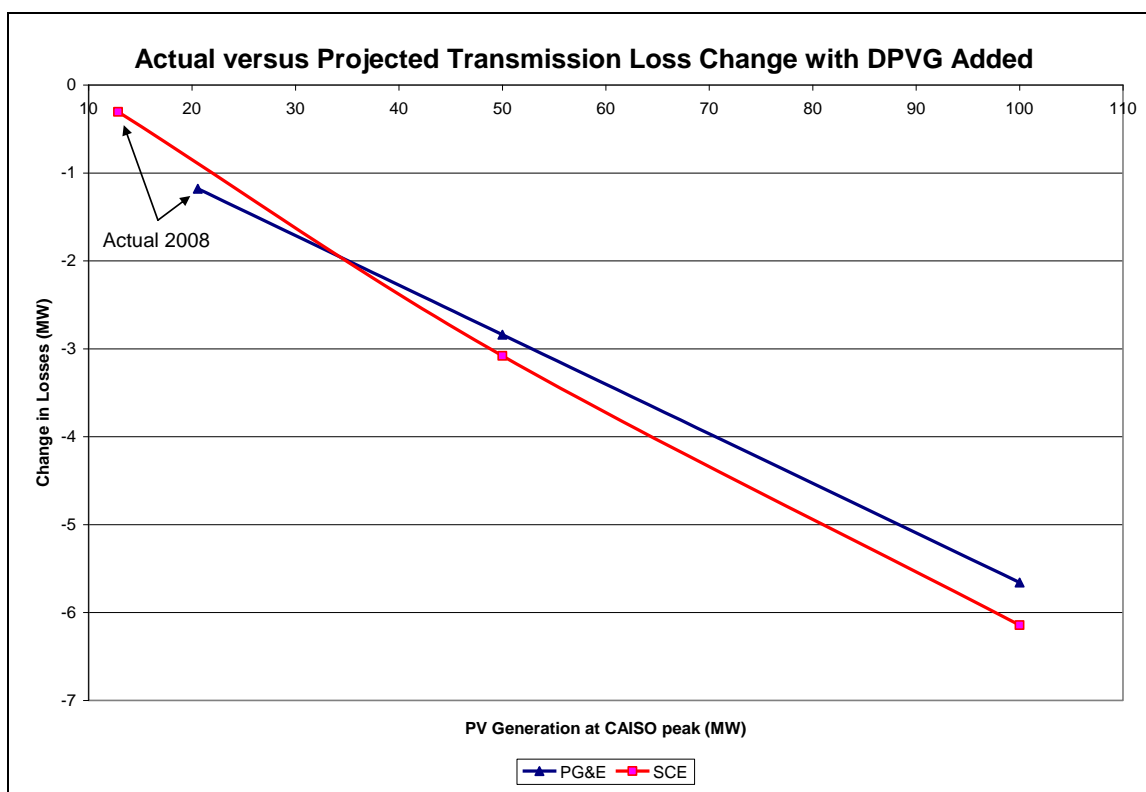


Figure B-8: Impact of Additional PV Generation on Transmission Losses

Distribution System Impacts

Similar to the transmission system situation, the total CSI PV capacity installed in 2008 is small compared to the net load on California distribution circuits. Nonetheless, there were a number of distribution circuits where the impact of CSI PV capacity was significant. In particular, this tended to occur on distribution feeder circuits with larger PV generating systems associated with industrial or commercial utility customers.

The 2008 distribution impact analysis addresses the impact of several of these large PV sites on actual utility circuits. The analysis explores the impact on both distribution circuit delivery capacity and losses. Comprehensive PV metering and circuit data was not available for 2008. Consequently, the goal for the 2008 distribution analysis was primarily to develop examples of analysis based on a combination of utility supplied circuit and select PV performance data. It is intended that lessons learned from these examples will be used to develop a more comprehensive distribution impact analysis for the 2009 impacts evaluation.

Methodology for Estimating Distribution System Impacts

Utility electric distribution circuits are typically designed to deliver power generated by centrally-located sources to end-use customers. The addition of PV generation to these

circuits as distributed energy sources usually impacts a number of factors associated with delivery performance including:

- *Capacity Margin* - refers to the degree that circuit elements are operating close to rated current or “ampacity.”
- *Power Delivery Losses* –refers to the amount of energy lost due to conductor heating and transformer inefficiencies.
- *Voltage Regulation* – the degree to which customer voltages are kept within acceptable ranges.
- *System Reliability* –relates to the duration and frequency of sustained and momentary outages experienced by customers.

The impact of PV generation on a distribution circuit is a function of the amount and location of the PV generation, as well as the characteristics of the distribution circuit. A circuit-specific locational analysis based on engineering analysis is used to quantify the impacts. In turn, this requires an electrical model of the distribution circuit being analyzed along with its load characteristics, together with a representation of the PV systems. The analysis then compares how the circuit would operate with and without the PV generation.

Building this type of model for distribution impact analysis requires the following three steps:

1. Obtaining a connectivity model from the utility that represents the electrical characteristics of the circuit and how customer load is interconnected.
2. Obtaining substation loading data for the circuit from the utility that indicates how much electrical load was present as a function of dates and times.
3. Obtaining metered generation data from PV sites as a function of dates and times.

Combining these three types of information makes it possible to simulate the specific distribution circuit and the locational impact of PV generation. The 2008 impact analysis focused on summer peak loading conditions since this is the most critical condition for distribution circuit capacity planning purposes.

Provided PV Performance Data

Metered PV generation data from 2008 was provided for CSI PV systems located in the PG&E and SCE territories.

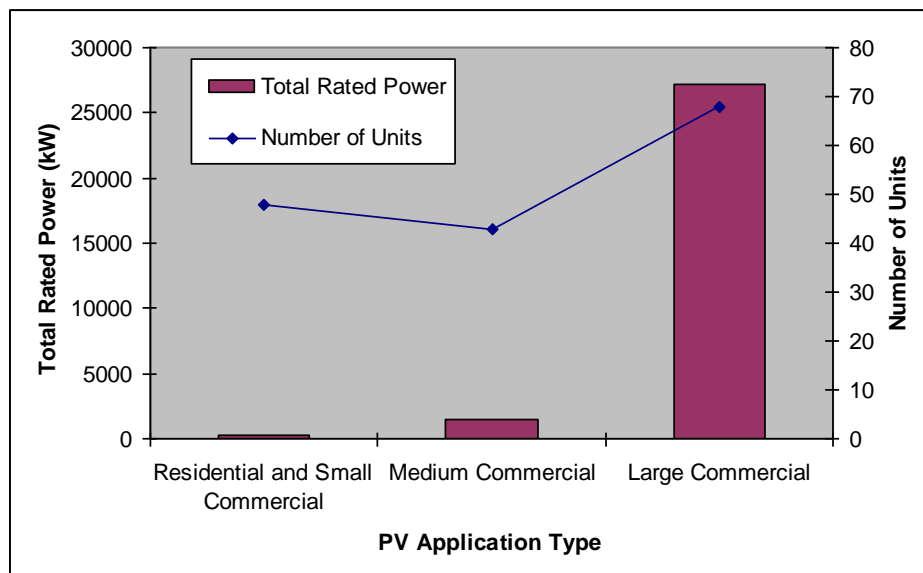
Data available for PG&E PV Sites

For the PG&E service area PV site performance data was available from 159 sites. The PV data represented a total CEC PTC capacity of 28.9 MW that could be correlated to the respective distribution circuits. Figure B-9 shows the distribution of PV unit sizes examined in the PG&E analysis, where:

Residential and Small Commercial	$0 < \text{CEC PTC} \leq 10 \text{ kW}$
Medium Commercial	$10 \text{ kW} < \text{CEC PTC} \leq 100 \text{ kW}$
Large Commercial	$100 \text{ kW} < \text{CEC PTC}$

The bulk of the PV generation capacity for which 2008 data was available represents large commercial units above 100 kW. The remainder is provided by medium commercial, residential and small commercial units.

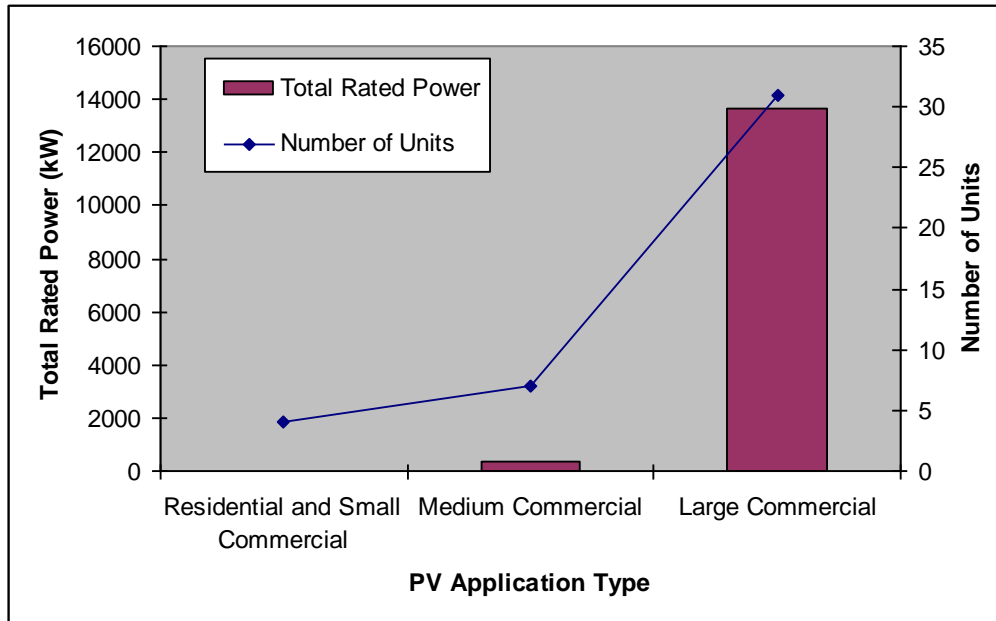
Figure B-9: Total Capacity and Number of PV Sites by Category for PG&E Service Territory



Data available for SCE PV Sites

PV site performance data for SCE included measurements from 42 sites. These sites represented a total CEC PTC capacity of 14.0 MW that could be correlated to the respective distribution feeders. Figure B-10 shows the distribution of the PV customers by unit size for SCE. Note that the bulk of the PV generation capacity with data available is from Large Commercial units above 100 kW

Figure B-10: Total Capacity and Number of PV Sites by Category for SCE Service Territory



Resulting Locational Analysis Examples

PG&E Circuit Selection and Examples

The focus of the 2008 distribution analysis was several distribution circuit impact examples corresponding to the 2008 summer peak period. Typically at least 100 kW of PV generation would be needed to see much of an impact on circuit performance. Table B-14 summarizes information on the four selected distribution circuits and the capacities of the PV systems associated with the circuits.

Table B-14: PG&E Distribution Circuits and Associated PV Capacities

Circuit	Location	Approximate PV Capacity (kW)
Pleasant Grove 2107	Rocklin	500-1000kW
Foothill 1102	San Luis Obispo	251-499kW
Basalt 1106	Napa	100-250kW
Silverado 2103	Rutherford	100-250kW

The data provided by PG&E included a connectivity model and historical feeder demand measurements for each of the selected feeders. The connectivity model included information on the line types and lengths, customer load sizes, transformer connections between customers and the lines, and other quantities needed to build an electric circuit model.

Based on this connectivity data a three-phase power flow model was built for each circuit to be analyzed. The three-phase power flow was used to calculate electric circuit power flows for each branch in the circuit as well as bus voltages. The individual PV sites were modeled as generation sources. Due to the absence of individual phase loading data, it was assumed that 2008 loading was balanced (equal) on each of the three phases.

Results for each circuit example are described below. However, due to unresolved discrepancies in its loading data set, Basalt 1106 was removed from the following analysis. Actual circuit power flow calculations were done using circuit "mega-volt-amperes" (MVA), but the results were expressed as "mega-watts" (MW) for the purposes of this report.

Circuit Example 1 - Silverado 2103

Circuit characteristics of the Silverado 2103 circuit are shown in Table B-15. The customer mix is heavily industrial (nearly 70 percent of the load) followed with an almost equal balance of the remaining 30 percent of the load due to residential and commercial customers. The 2008 summer peak loading for the Silverado 2103 circuit occurred on August 28th starting at 3:50 p.m.

Table B-15: Circuit Characteristics of Silverado 2103

<i>Circuit Features</i>	
City	Rutherford
Climate	
Voltage (kV)	20.78
<i>Percent Load Mix (by kWh)</i>	
Residential	14.6%
Commercial	11.5%
Industrial	69.9%
Agriculture	4.1%
Other	0.0%
<i>Peak Circuit Load Characteristics</i>	
2008 Summer Peak MW	11.3
2008 Summer Peak Date	28-Aug
2008 Summer Peak Time	15:50
2008 Winter Peak MW	9
2008 Winter Peak Date	7-Oct
2008 Winter Peak Time	15:20

A summary of the distribution circuit analysis for the Silverado 1203 circuit is shown in Table B-16. Figure B-11 shows the hour by hour loading on the circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-12.

Table B-16: Summary of Analysis on Silverado 1203 Circuit

Circuit Power Flow Characteristics	
Peak Percent Primary Power Loss	1.6%
Maximum Percent Voltage Drop	1.71%
Locational Impacts at 2008 Summer Peak	
PV Contribution at time of Peak Load (kW)	69.8
Percent Peak Contribution	0.6%
Peak kW Loss Reduction	3
Percent kW Peak Loss Reduction	1.7%
Daily kWh Reduction	990
Percent kWh Reduction	0.5%

Figure B-11: Silverado 1203 Circuit Loading Recorded at Substation vs. Hourly PV Generation

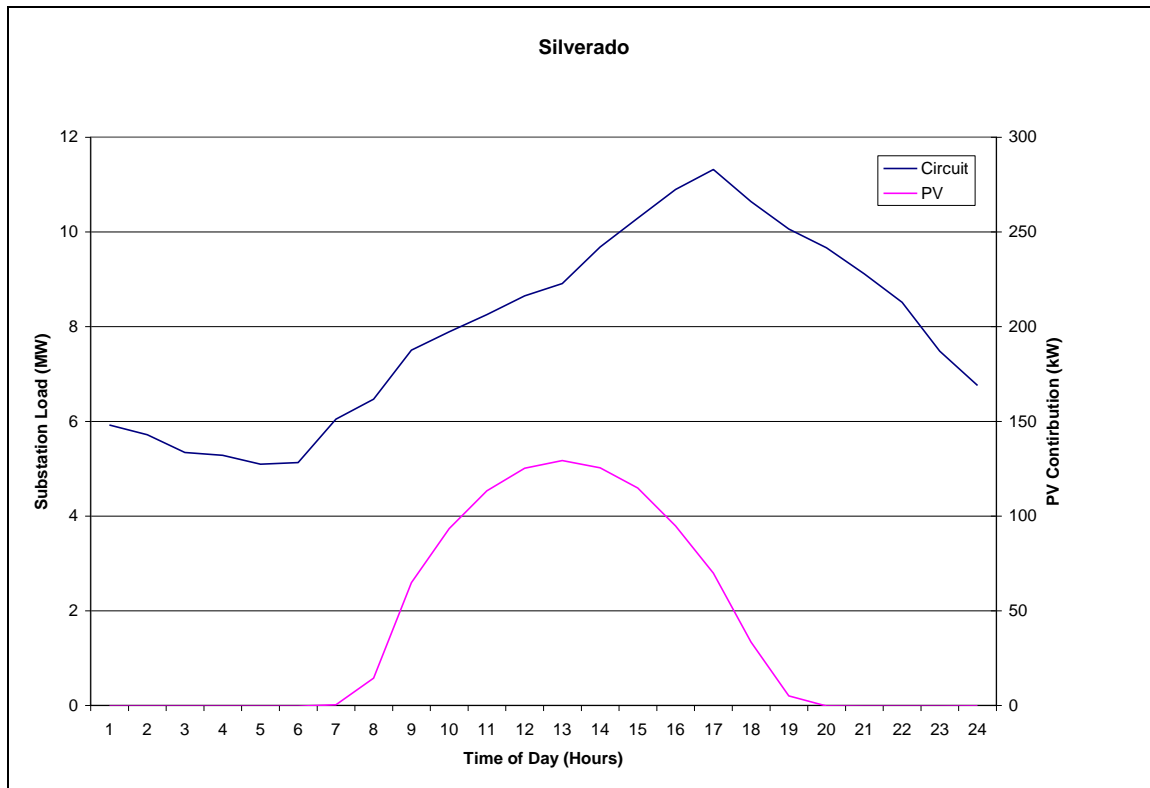
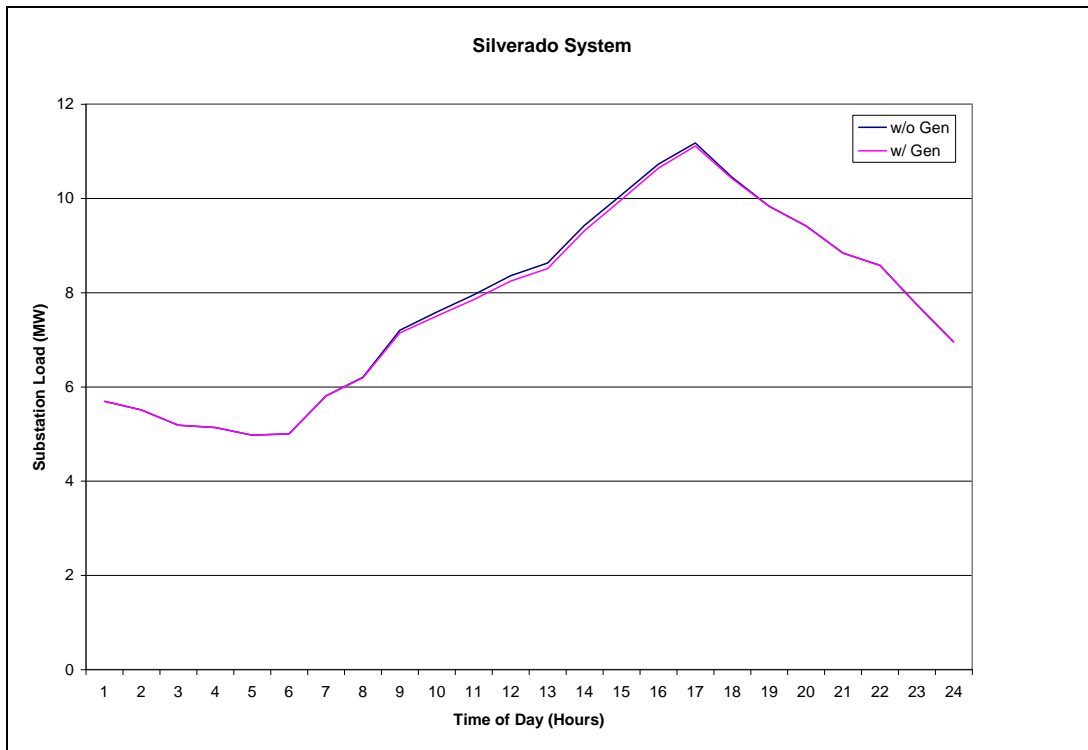


Figure B-12: Silverado 1203 Circuit Loading with and without PV Contribution



Circuit Example 2 - Pleasant Grove 2107

Circuit characteristics for the Pleasant Grove 2107 circuit are shown in Table B-17. The load is heavily influenced by industrial customers (nearly 66 percent of the load) with the remaining load due to residential customers. The 2008 peak summer loading on the circuit occurred on June 18th beginning at 5:50 p.m.

Table B-17: Characteristics of Pleasant Grove 2107 Circuit

<i>Circuit Features</i>	
City	Rocklin
Climate	
Voltage (kV)	20.78
<i>Percent Load Mix (by kWh)</i>	
Residential	26.1%
Commercial	8.0%
Industrial	65.9%
Agriculture	0.0%
Other	0.0%
<i>Peak Circuit Load Characteristics</i>	
2008 Summer Peak MW	14.1
2008 Summer Peak Date	18-Jun
2008 Summer Peak Time	17:50
2008 Winter Peak MW	9.2
2008 Winter Peak Date	29-Jan
2008 Winter Peak Time	18:00

A summary of the distribution circuit analysis is shown in Table B-18. Figure B-13 shows the hour by hour loading on the circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-14.

Table B-18: Summary of Analysis on Pleasant Grove 2107 Circuit

Circuit Power Flow Characteristics	
Peak Percent Primary Power Loss	1.1%
Maximum Percent Voltage Drop	1.43%
Locational Impacts at 2008 Summer Peak	
PV Contribution at Peak Load (kW)	313
Percent Peak Contribution	2.2%
Peak kW Loss Reduction	4
Percent kW Peak Loss Reduction	2.4%
Daily kWh Reduction	7742
Percent kWh Reduction	3.1%

Figure B-13: Pleasant Grove 2107 Circuit Loading Recorded at Substation vs. Hourly PV Generation

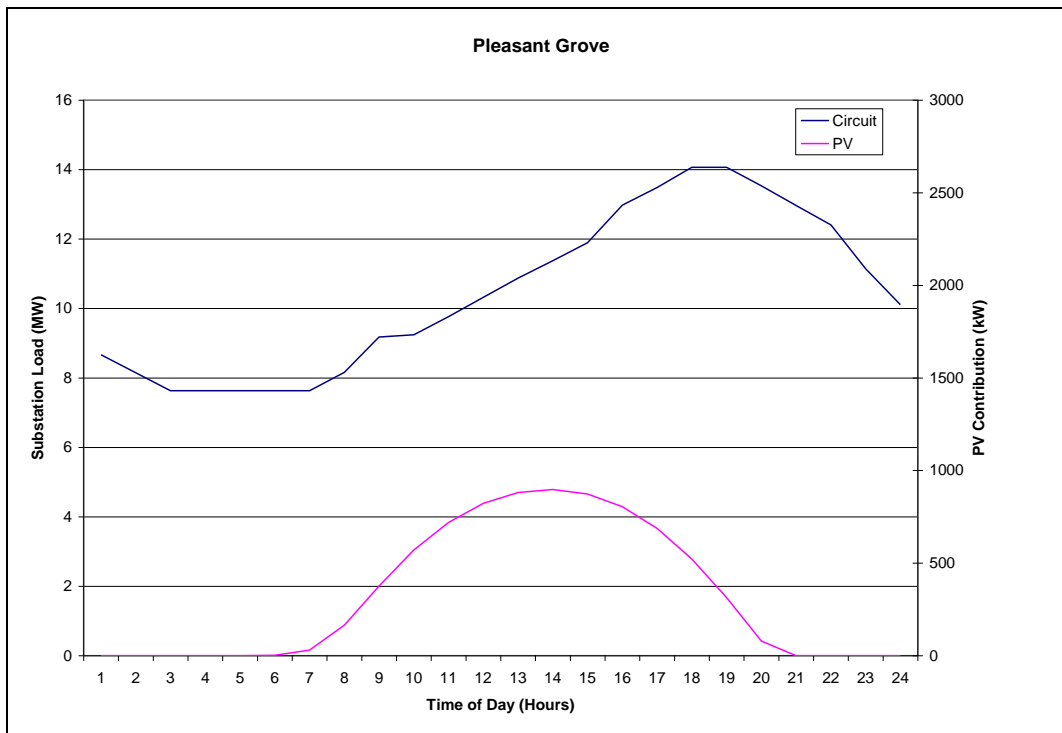
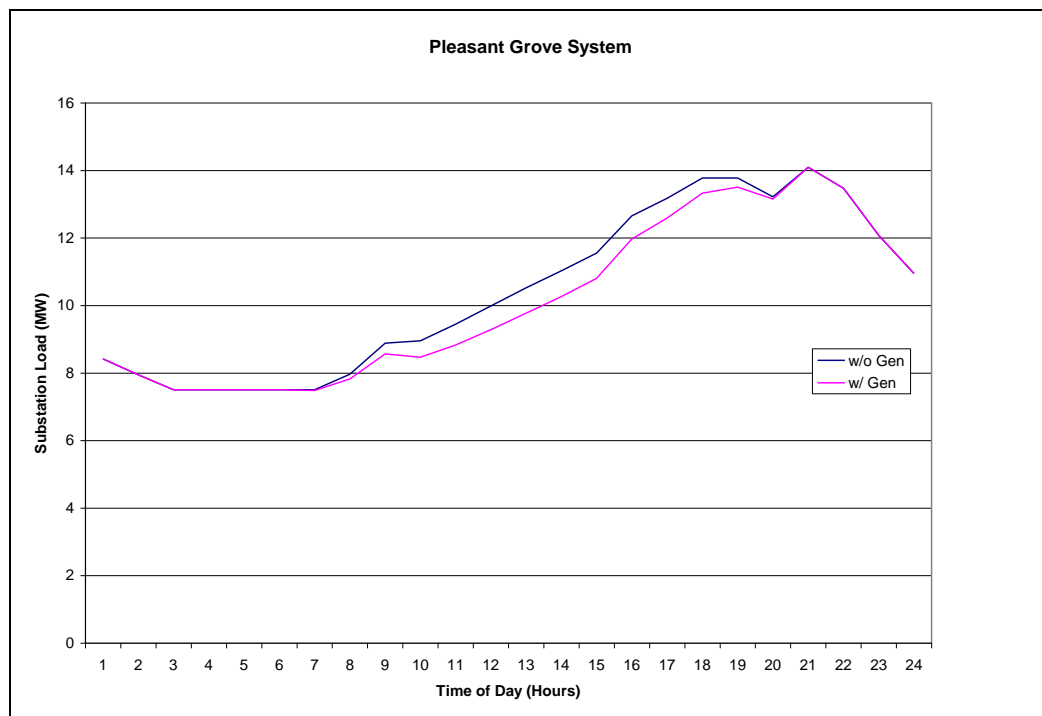


Figure B-14: Pleasant Grove 2107 Circuit Loading with and without PV Contribution



Circuit Example 3 – Foothills 1102

Circuit characteristics for the Foothills 1102 circuit are shown in Table B-19. Similar to both the Silverado and Pleasant Grove circuits, the load is heavily influenced by industrial customers (nearly 50 percent of the load). The remaining load is due primarily to residential customers. The 2008 peak summer loading on the circuit occurred on June 20th beginning at 4:00 p.m.

Table B-19: Characteristics of Foothills 1102 Circuit

Circuit Features	
City	San Luis Obispo
Climate	
Voltage (kV)	12.47
Percent Load Mix (by kWh)	
Residential	43.8%
Commercial	5.6%
Industrial	50.4%
Agriculture	0.1%
Other	0.1%
Peak Circuit Load Characteristics	
2008 Summer Peak MW	7.3
2008 Summer Peak Date	20-Jun
2008 Summer Peak Time	16:00
2008 Winter Peak MW	9
2008 Winter Peak Date	23-Jan
2008 Winter Peak Time	18:30

A summary of the Foothills 1102 distribution circuit analysis is shown in Table B-20.

Table B-20: Summary of Analysis on Foothills 1102 Circuit

Circuit Power Flow Characteristics	
Peak Percent Primary Power Loss	4.7%
Maximum Percent Voltage Drop	5.44%
Locational Impacts at 2008 Summer Peak	
PV Contribution at Peak Load (kW) (Note 1)	347
Percent Peak Contribution	4.5%
kW Peak Loss Reduction	8
Percent kW Peak Loss Reduction	2.2%
Daily kWh Reduction	3140
Percent kWh Reduction	2.2%

Figure B-15 shows the hour by hour loading on the circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-16.

Figure B-15: Foothills 1102 Circuit Loading Recorded at Substation vs. Hourly PV Generation

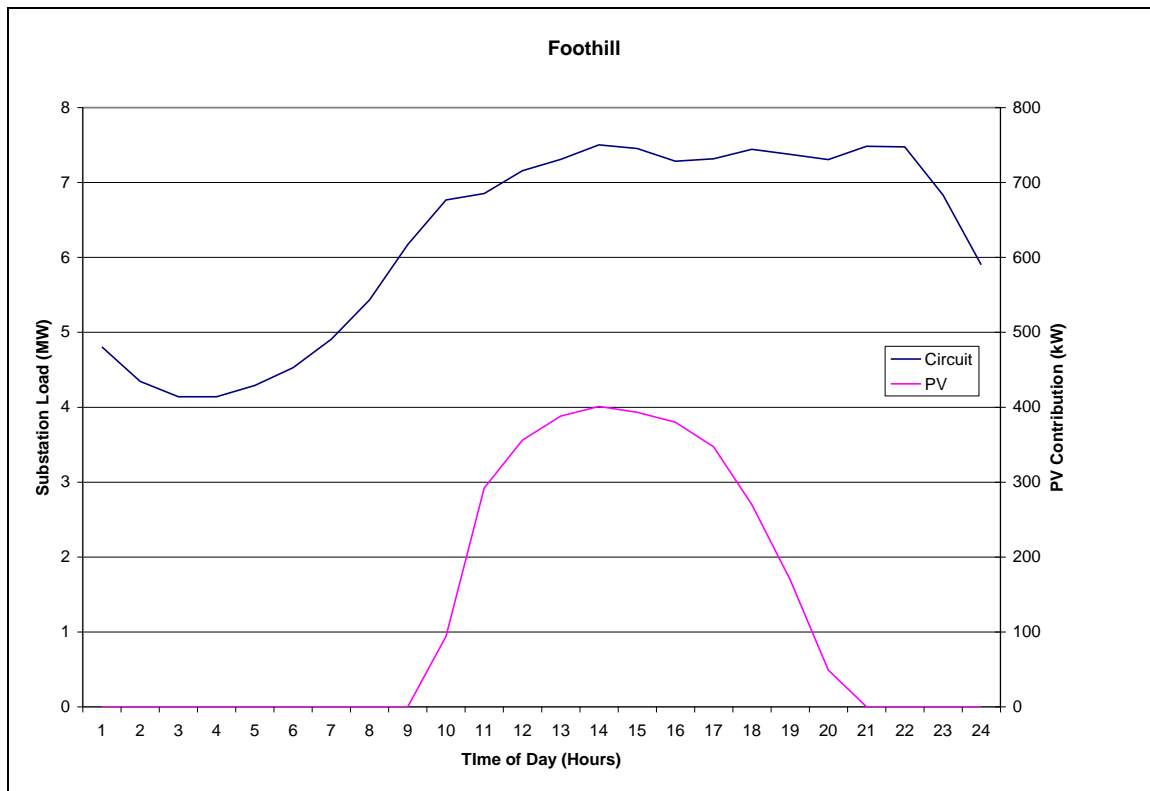
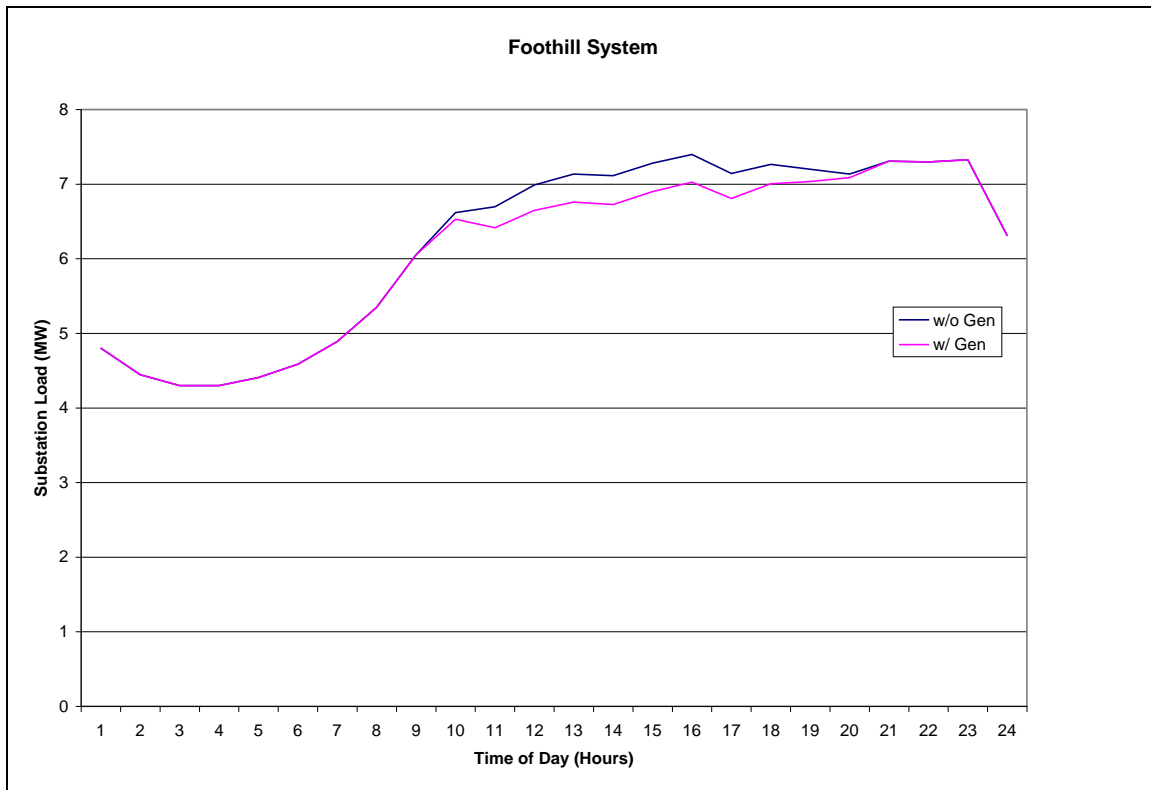


Figure B-16: Foothills 1102 Circuit Loading with and without PV Contribution



Summary of PG&E Distribution Circuit Examples

Table B-21 is a summary of the circuit analyses conducted on the sample PG&E circuits. In general, the CSI PV systems located on the circuits demonstrated a modest impact on reducing the summer peak loading of the circuits; generally less than 2.5 percent of the peak loading. Similarly, daily load reductions due to the CSI PV systems were generally less than 3 percent of the daily circuit loads. However, these analyses represent a low amount of PV capacity on the selected distribution circuits. A higher capacity of PV capacity on the distribution circuit could possibly show higher load reductions. One focus of the distribution systems analysis for the 2009 impact evaluation will be to examine circuits with higher installed PV capacities.

Table B-21: Summary of PG&E Example Circuit Analyses

Circuit	Silverado 2103	Foothills 1102	Pleasant Grove 2107
<i>Circuit Features</i>			
City	Rutherford	San Luis Obispo	Rocklin
Climate			
Voltage (kV)	20.78	12.47	20.78
<i>Percent Load Mix (by kWh)</i>			
Residential	14.6%	43.8%	26.1%
Commercial	11.5%	5.6%	8.0%
Industrial	69.9%	50.4%	65.9%
Agriculture	4.1%	0.1%	0.0%
Other	0.0%	0.1%	0.0%
<i>Peak Circuit Load Characteristics</i>			
2008 Summer Peak MW	11.3	7.3	14.1
2008 Summer Peak Day	28-Aug	20-Jun	18-Jun
2008 Summer Peak Time	15:50	16:00	17:50
2008 Winter Peak MW	9	9	9.2
2008 Winter Peak Day	7-Oct	23-Jan	29-Jan
2008 Winter Peak Time	15:20	18:30	18:00
<i>Circuit Power Flow Characteristics</i>			
Peak Percent Primary Power Loss	1.6%	4.7%	1.1%
Maximum Percent Voltage Drop	1.71%	5.44%	1.43%
<i>Locational Impacts at 2008 Summer Peak</i>			
PV Contribution to Peak Load (kW)	69.8	347	313
Percent Peak Contribution	0.6%	4.5%	2.2%
kW Peak Loss Reduction	3	8	4
Percent kW Peak Loss Reduction	1.7%	2.2%	2.4%
Daily kWh Reduction	990	3140	7742
Percent kWh Reduction	0.5%	2.2%	3.1%

SCE Circuit Selection and Examples

Detailed circuit modeling was not available for SCE circuits in the 2008 impact analysis. However, PV generation contribution was analyzed with respect to circuit summer peak load profiles for selected circuits. Note that circuit loading data obtained from SCE was provided in “amperes” and unity power factor was assumed for converting between amperes and power (MW).

Circuit Example 1 - Glen Ridge 7346

Circuit characteristics of the Glen Ridge 7346 circuit are shown in Table B-22. The 2008 summer peak loading for the circuit occurred on June 20th starting at 4:00 p.m.

Table B-22: Characteristics of Glen Ridge 7346 Circuit

<i>Circuit Features</i>	
City	Chino
Climate	Inland
Voltage	12 kV
<i>Peak Load Characteristics</i>	
2008 Summer Peak Power (MW)	10.5
2008 Summer Peak Day	20-Jun
2008 Summer Peak Time	16:00

A summary of the Glen Ridge 7346 distribution circuit analysis is shown in Table B-23.

Table B-23: Summary of Analysis on Glen Ridge 7346 Circuit

<i>PV Site Characteristics</i>	
Maximum Output on 2008 Summer Peak Day (kW)	550
PV Penetration Level as % of Circuit Capacity on 2008 Summer Peak Day	5.2%
<i>Locational Impacts at 2008 Summer Peak</i>	
Percent of Circuit Capacity Released	3.6%

Figure B-17 shows the hour by hour loading on the Glen Ridge 7346 circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-18.

Figure B-17: Glen Ridge 7346 Circuit Loading Recorded at Substation vs. Hourly PV Generation

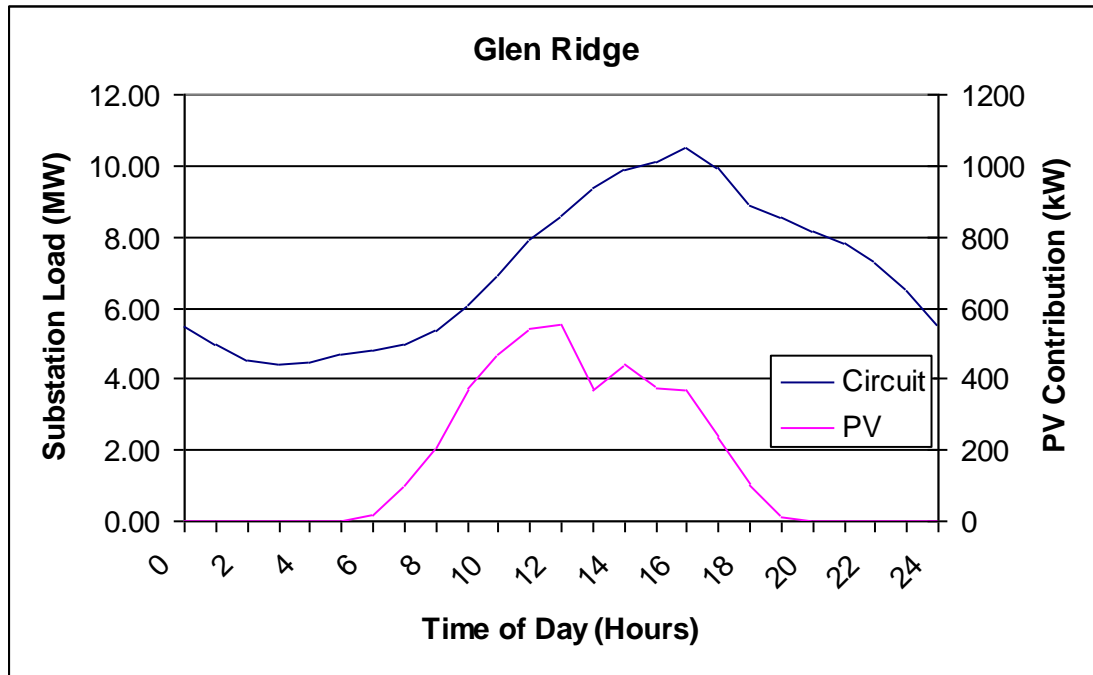
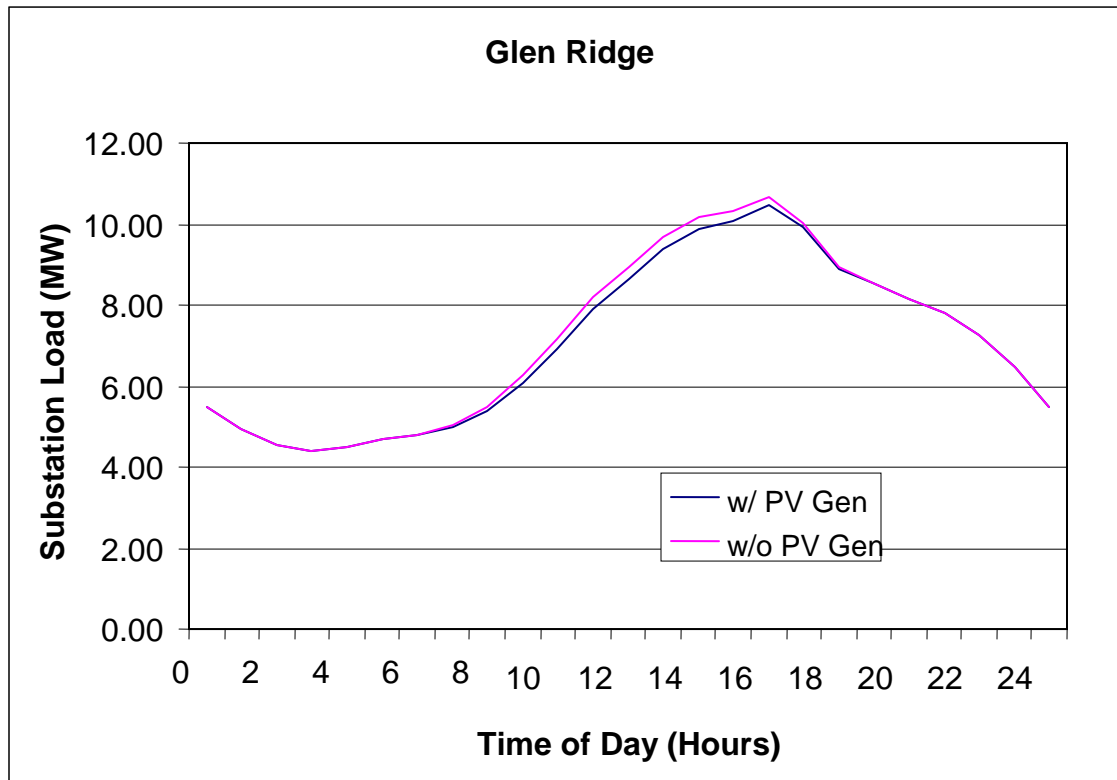


Figure B-18: Glen Ridge 7346 Circuit Loading with and without PV Contribution



Circuit Example 2 – Violin 18793

Circuit characteristics of Violin 18793 circuit are shown in Table B-24. The 2008 summer peak loading for the circuit occurred on June 20th starting at 4:00 p.m.

Table B-24: Characteristics of Violin 18793 Circuit

<i>Circuit Features</i>	
City	Laguna Niguel
Climate	Coastal
Voltage	12 kV
<i>Peak Load Characteristics</i>	
2008 Summer Peak Power (MW)	8.0
2008 Summer Peak Day	1-Oct
2008 Summer Peak Time	16:00

A summary of the Violin 18793 distribution circuit analysis is shown in Table B-25.

Table B-25: Summary of Analysis on Violin 18793 Circuit

<i>PV Site Characteristics</i>	
Maximum Output on 2008 Summer Peak Day (kW)	311
PV Penetration Level as a % of circuit capacity on 2008 Summer Peak Day	3.9%
<i>Locational Impacts at 2008 Summer Peak</i>	
Percent of Circuit Capacity Released	1.8%

Figure B-19 shows the hour by hour loading on the Violin 18793 circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-20.

Figure B-19: Violin 18793 Circuit Loading Recorded at Substation vs. Hourly PV Generation

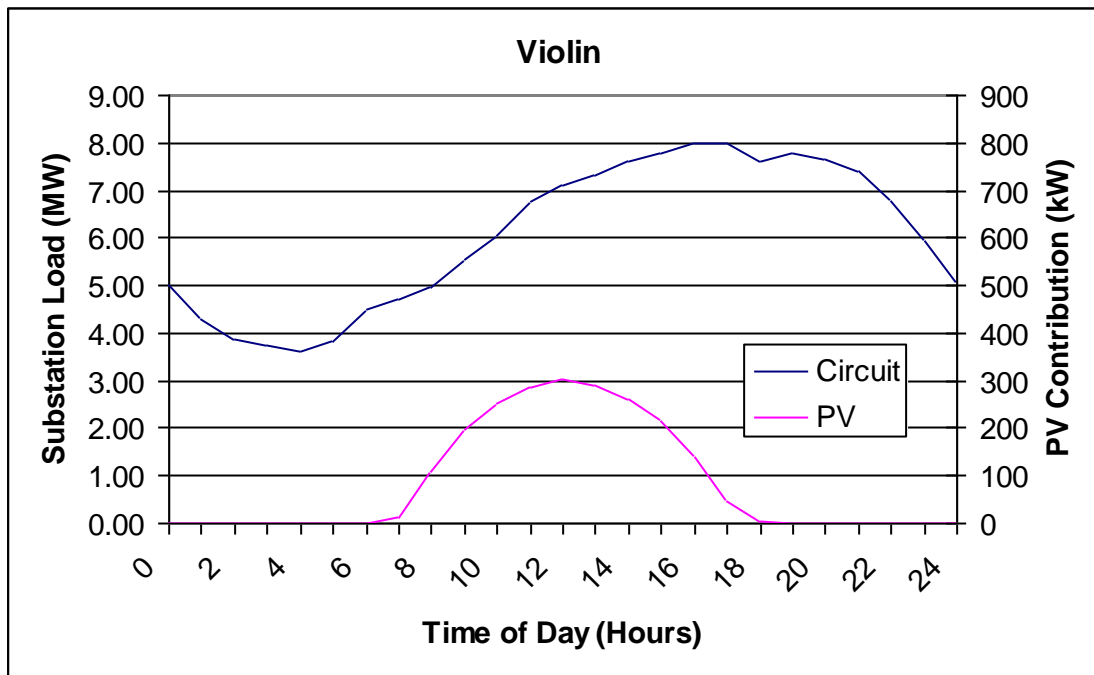
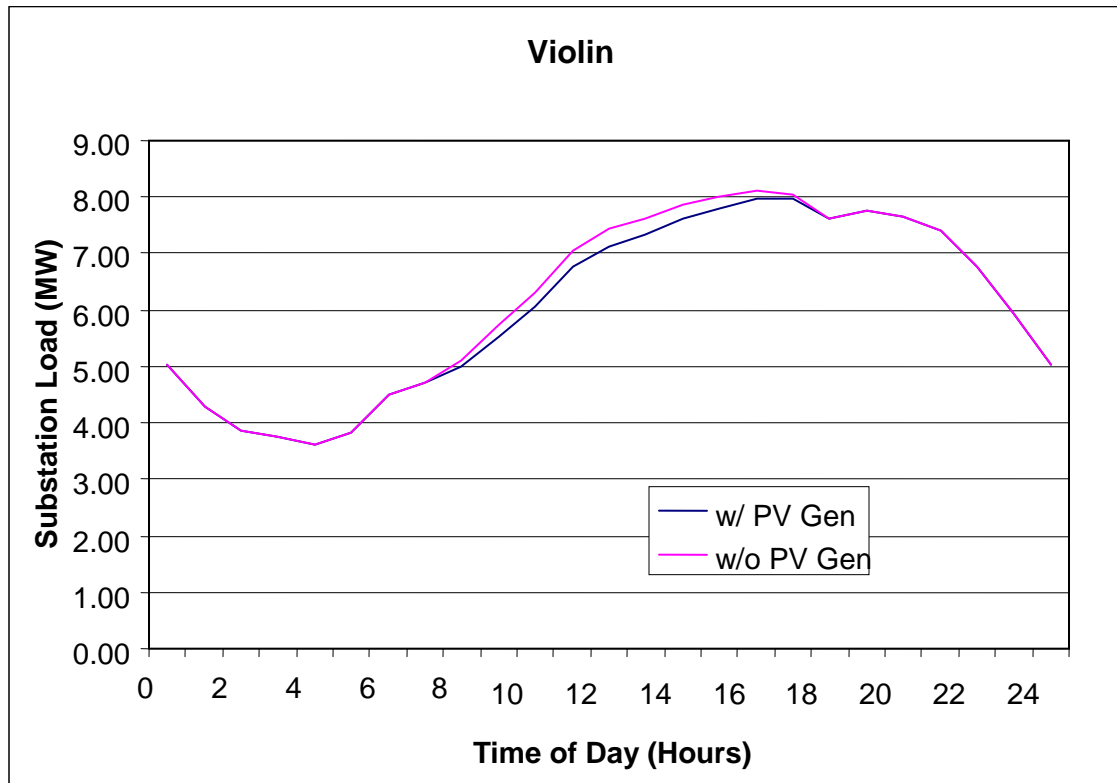


Figure B-20: Violin 18793 Circuit Loading with and without PV Contribution



Circuit Example 3 – Chanslor 03333

Circuit characteristics of the Chanslor 03333 circuit are shown in Table B-26. The 2008 summer peak loading for the circuit occurred on June 27th starting at 4:00 p.m.

Table B-26: Characteristics of Chanslor 03333 Circuit

<i>Circuit Features</i>	
City	Blythe
Climate	Far Inland
Voltage	33 kV
<i>Peak Load Characteristics</i>	
2008 Summer Peak Power (MW)	13.6
2008 Summer Peak Day	27-Jun
2008 Summer Peak Time	16:00

A summary of the Chanslor 03333 distribution circuit analysis is shown in Table B-27.

Table B-27: Summary of Analysis on Chanslor 03333 Circuit

<i>PV Site Characteristics</i>	
Maximum Output on 2008 Summer Peak Day (kW)	873
PV Percent Penetration Level on 2008 Summer Peak Day	6.4%
<i>Locational Impacts at 2008 Summer Peak</i>	
PV Contribution at Peak Load (kW)	456.1
Percent Capacity Release	3.5%

Figure B-21 shows the hour by hour loading on the Chanslor 03333 circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-22.

Figure B-21: Chanslor 03333 Circuit Loading Recorded at Substation vs. Hourly PV Generation

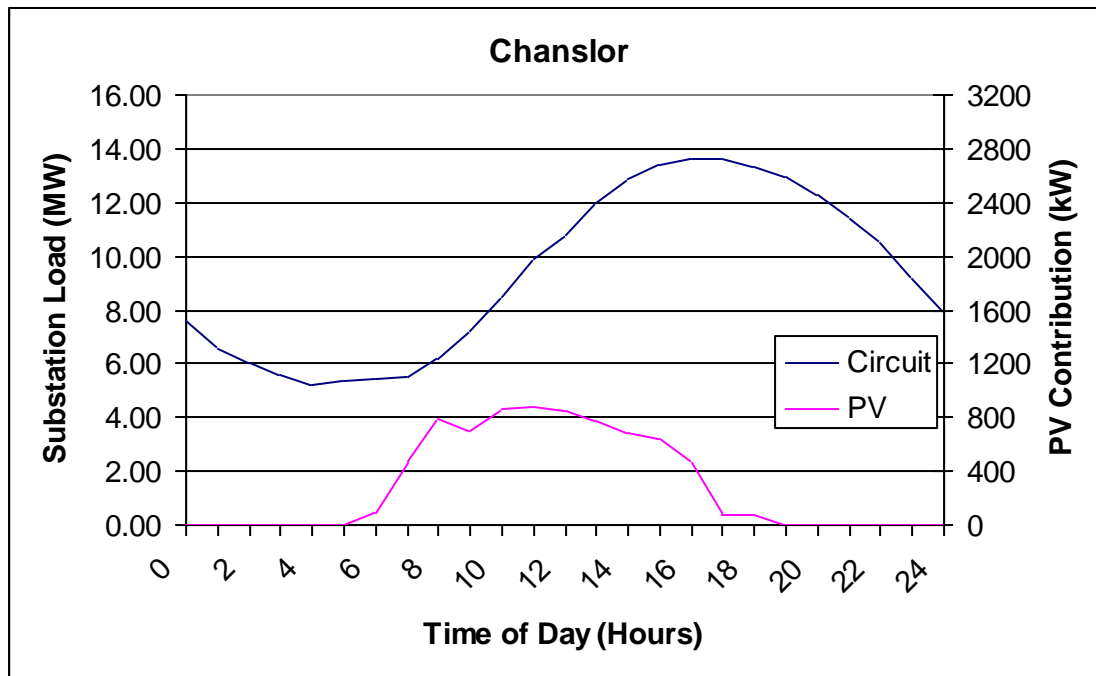
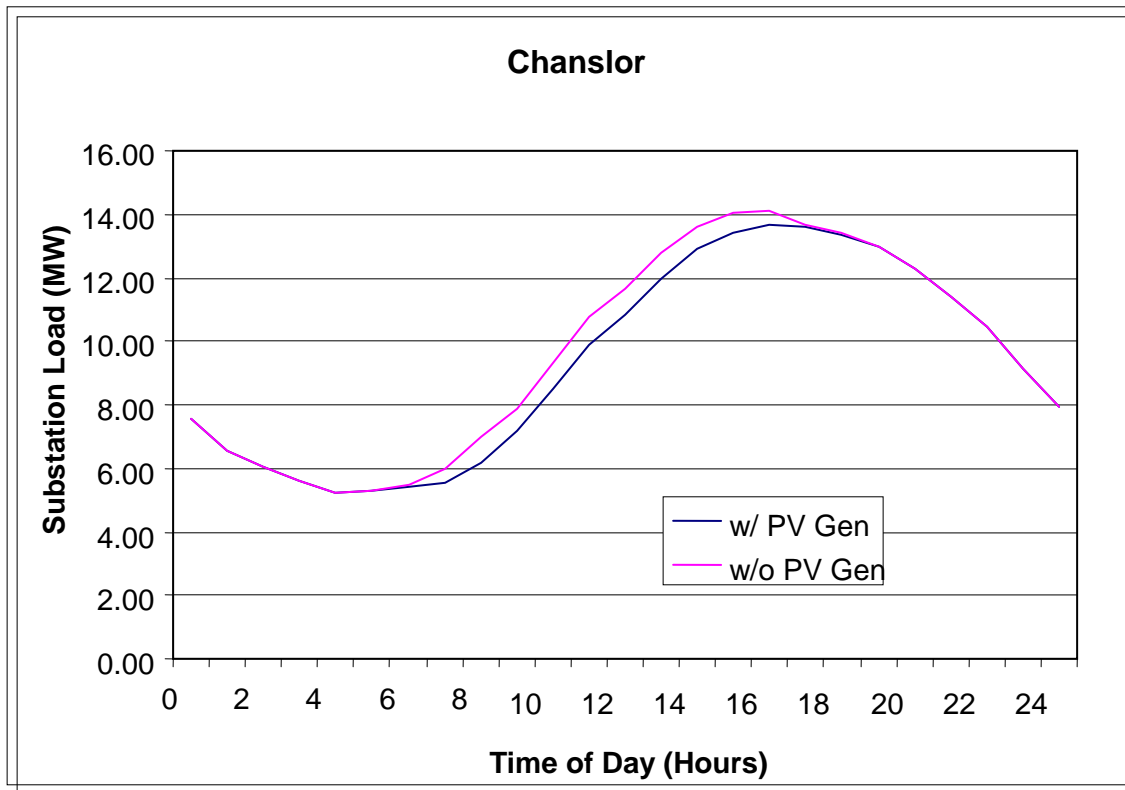


Figure B-22: Chanslor 03333Circuit Loading with and without PV Contribution



Circuit Example 4 – Higby 8405

Circuit characteristics of the Higby 8405 circuit are shown in Table B-28. The 2008 summer peak loading for the circuit occurred on June 27th starting at 4:00 p.m.

Table B-28: Characteristics of Higby 8405 Circuit

<i>Circuit Features</i>	
City	Visalia
Climate	Inland
Voltage	12 kV
<i>Peak Load Characteristics</i>	
2008 Summer Peak Power (MW)	9.8
2008 Summer Peak Day	10-Jul
2008 Summer Peak Time	18:00

Table B-29: Summary of Analysis on Higby 8405 Circuit

<i>PV Site Characteristics</i>	
Maximum Output on 2008 Summer Peak Day (kW)	60
PV Percent Penetration Level on 2008 Summer Peak Day	0.6%
<i>Locational Impacts at 2008 Summer Peak</i>	
PV Contribution at Peak Load (kW)	6.5
Percent Capacity Release	0.1%

Figure B-23 shows the hour by hour loading on the Higby 8405 circuit against the PV hourly generation profile. The impact of the PV system on the circuit on an hour by hour basis during the summer peak is displayed in Figure B-24.

Figure B-23: Higby 8405 Circuit Loading Recorded at Substation vs. Hourly PV Generation

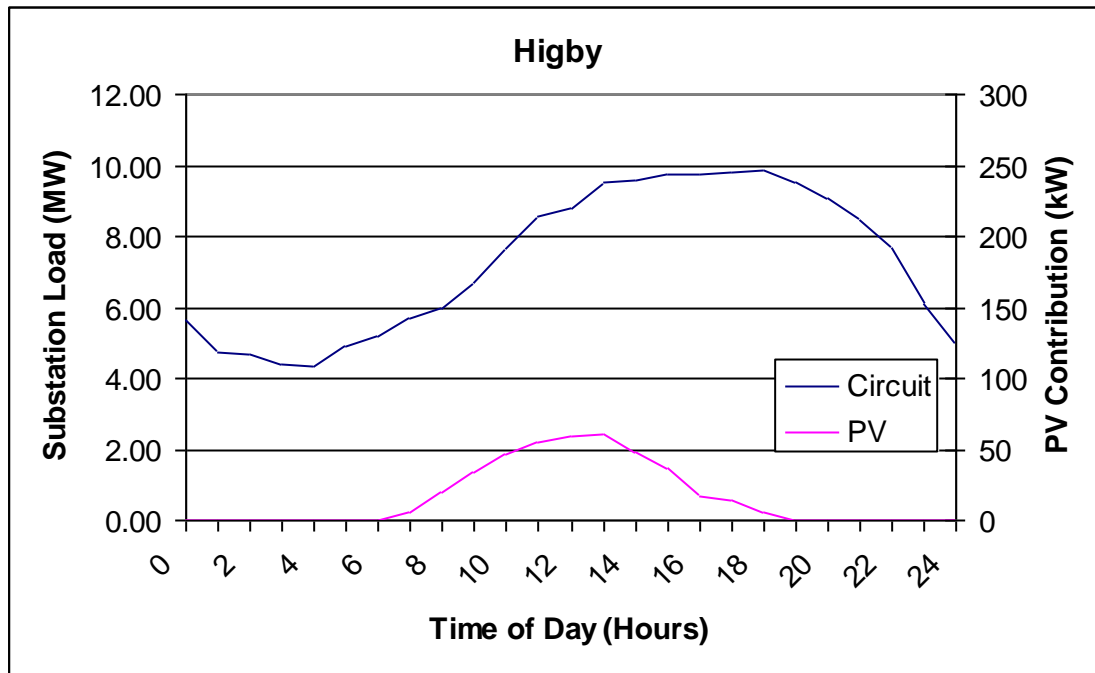
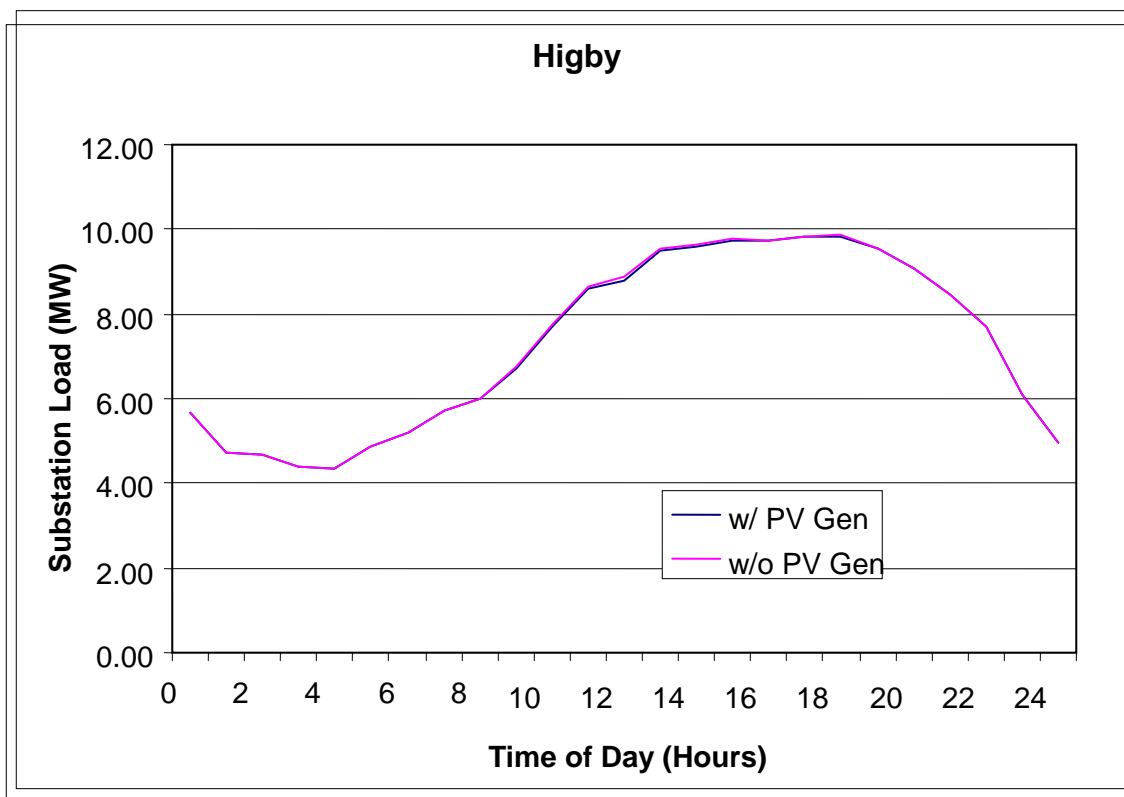


Figure B-24: Higby 8405 Circuit Loading with and without PV Contribution



Summary of SCE Distribution Circuit Examples

Table B-30 is a summary of the circuit analyses conducted on the sample SCE circuits. Similar to the results seen with the PG&E circuits, the CSI PV systems located on the SCE circuits also demonstrated a modest impact on reducing the summer peak loading of the circuits. In general, the peak load reduction was less than 4 percent of the peak loading. As with the PG&E circuits, it should be noted that these analyses represent a low amount of PV capacity on the selected distribution circuits.

Table B-30: Summary of SCE Example Circuit Analyses

Circuit	Glen Ridge 7346	Violin 18793	Chanslor 03333	Higby 8405
<i>Circuit Features</i>				
City	Chino	Laguna Niguel	Blythe	Visalia
Climate	Inland	Coastal	Far Inland	Inland
Voltage	12 kV	12 kV	33 kV	12 kV
<i>Peak Circuit Load Characteristics</i>				
2008 Summer Peak Power (MW)	10.5	8.0	13.6	9.8
2008 Summer Peak Day	20-Jun	1-Oct	27-Jun	10-Jul
2008 Summer Peak Time	16:00	16:00	16:00	18:00
<i>PV Site Characteristics</i>				
Maximum Output on 2008 Summer Peak Day (kW)	550	311	873	60
PV Percent Penetration Level on 2008 Summer Peak Day	5.2%	3.9%	6.4%	0.6%
<i>Locational Impacts at 2008 Summer Peak</i>				
PV Contribution to Peak Load (kW)	366.6	139.7	456.1	6.5
Percent Capacity Release	3.6%	1.8%	3.5%	0.1%

Overall Conclusions of Distribution System Analyses

Based on the available PV generation data and the circuit loading information, the following conclusions can be made about the impact of CSI PV generation on the PG&E and SCE distribution systems:

1. The peak power output of PV facilities on the PG&E and SCE circuits analyzed in most cases occurred earlier than the daily peak load on the circuits under 2008 summer peak loading conditions, but a varying degree of overlap was still observed.

2. This overlap resulted in some reduction of 2008 peak circuit loading (thus increasing the useable circuit capacity) by 0.1-3.6% for the SCE circuits and 0.5-3.1% for the PG&E circuits, respectively.
3. As a result of the local PV generation, electrical heating losses on the PG&E distribution circuits analyzed were reduced from 1.7-2.4% at the time of peak circuit loading. (Note –corresponding 2008 results are unavailable for SCE circuits.)
4. The presence of PV generation on a circuit can shift the time of the peak (net) circuit loading as measured at the respective substation.

B.5 Greenhouse Gas Emission Impacts

Interest in climate change has increased over the last several years with special emphasis being placed on reducing greenhouse gas (GHG) emissions. Obtaining accurate measures of reductions in GHG emissions will increase in importance, particularly in the event of a cap and trade program for carbon credits. This section describes the impacts the installation of CSI projects had on CO₂ emissions in 2008.

GHG Analysis Approach

For the purposes of this impact evaluation, Itron has assumed that the vast majority of GHG emission reductions associated with CSI facilities are due to reduced CO₂ emissions. PV systems convert sunlight to electricity via solid state processes and do not emit carbon dioxide (CO₂) as a result of those processes. Consequently, CSI installed PV reduces GHG emissions by displacing electricity that would otherwise have been generated by utility-based generation. Estimates of CSI-based GHG emission reductions during 2008 were based on estimates of electricity generated by the CSI PV systems rather than by centralized power plants. In turn, GHG emission rates for each kWhr of electricity generated from utility-based power plants were taken from hourly estimates developed by Energy and Environmental Economics (E3). E3 established hourly CO₂ emission estimates based on profiles of base-load power plants and peaking plants. Unlike base-load power plants, the operation of peaking plants varies throughout the year. E3 assumed the dispatch of peaking facilities was based on avoided costs (i.e., peaking facilities would be brought on line based on the need and marginal heat rate). As a result, E3 established an avoided costs workbook⁵ that provided hourly estimates of GHG impacts per kWh and which reflects a full year of hourly CO₂ emission factors.

⁵ Energy and Environmental Economics for the California Public Utilities Commission, “Methodology and Forecast of Long Term Avoided Costs for the Evaluation of California Energy Efficiency Programs,” October 25, 2004.

GHG Analysis Results

This section provides the GHG emissions reduction impacts that occurred as a result of the installation of PV under the CSI.

CO₂ Emission Impacts

PV installations result in a direct displacement of electricity that would have otherwise been generated from natural gas fired central station power plants. As a result, the CO₂ emission impacts were based on the amount of CO₂ that would have been generated by the mix of utility electricity generation sources. Table B-31 shows the impact of PV projects on CO₂-specific GHG emissions for each PA as well as a CSI program total impact.

Table B-31: CO₂ Emissions Impact through by Program Administrator (2008)

Program Administrator	CO2 Emissions Avoided (Tons)	Energy Impact (MWh)	CO2Eq Factor (Tons/MWh)
PG&E	48,413	79,933	0.61
SCE	31,548	49,767	0.63
CCSE	8,549	13,560	0.63
Total	88,511	143,259	0.62

Overall, the CSI provided nearly 89,000 tons of GHG emissions (as CO₂ equivalent) during 2008. Over 54 percent of the GHG emission reductions resulted from CSI PV systems installed in the PG&E service territory. In comparison, CSI PV facilities installed in the SCE and CCSE (SDG&E) regions resulted in approximately 36 percent and 10 percent of the overall 2008 GHG emission reductions, respectively.